

# THE SCIENTIFIC MONTHLY

MAY, 1943

## CHINA AND AMERICA AGAINST SOIL EROSION

### I. THE FATE OF CONSERVATION IN NORTHERN SHANSI

By Drs. W. C. LOWDERMILK and D. R. WICKES<sup>1</sup>

SOIL CONSERVATION SERVICE, U. S. DEPARTMENT OF AGRICULTURE

WAR of survival calls for our supreme effort. All resources, man-power and inanimate resources are called on to yield greater results. Experiments of the Soil Conservation Service throughout all farming areas of the country, have indicated that conservation measures greatly increase yields of crops. In such times our attention is called to China, where the use of land has gone through a wide range of trial and error for thousands of years. To find that conservation is not unknown in China's long history is of special interest to American scientists and historians of to-

day. Forces in civilization for and against conservation of material resources become apparent in the remarkable Chinese historical records and in the land itself, which bears a record of past land use.

Conservation of forests and soils has long been a problem and concern of the Chinese despite usual impressions gained from denuded hills of China. The senior author set forth the basis for this conclusion in 1930.<sup>2</sup> As far back as 300 B.C. one of the precepts of Mencius read as follows: "If ax and hatchet are used in forests at suitable intervals of time, then

<sup>1</sup> Assistant Chief and Soil Conservationist, respectively.

<sup>2</sup> *Annals of Amer. Acad. of Polit. and Social Science*, 152: Nov. 1930.



THE SENIOR AUTHOR'S EXPEDITION INTO SHANSI, CHINA  
FOR A STUDY OF LAND USE AT THE HEADWATERS OF THE FEN RIVER, IN 1925.



VIEW ACROSS THE VALLEY OF THE FEN RIVER

IN WHICH TUNG CHAI IS LOCATED, SHOWING A LANDSCAPE ONCE COVERED WITH SPRUCE-LARCH FORESTS. THE LAND IS CULTIVATED EVEN UP TO STEEP SLOPES AS SEEN IN THE RIGHT FOREGROUND, BRINGING ON DEVASTATING SOIL EROSION UNTIL MOST OF THE AREA HAS BEEN GENERALLY ABANDONED BY FARMERS, EXCEPT IN PATCHES, AS MAY BE NOTED IN THE MIDDLE FOREGROUND. NOW HERDS OF SHEEP RUN OVER THE ABANDONED FIELDS.

timber will be available when needed."<sup>3</sup> From ancient printed records of China, where the printing press was in use long before its discovery by Gutenberg,<sup>4</sup> there is evidence that conservation was not only understood and advocated but carried out for centuries. The Chinese have long been conservationists, second only perhaps to the ancient Phoenicians. The Chinese inherit an unbroken civilization

<sup>3</sup> Or in its context: If the seasons of agricultural work are not interfered with, grain will be more than can be eaten. If close-meshed nets are not used in pools or ponds, fish and turtles will be more than can be eaten. If ax and hatchet are used in forests at suitable times only, wood will be more than can be used. If grain, fish and turtles are more than can be eaten, and wood is more than can be used, this will cause the people to nourish the living and bury the dead without resentment. This condition, in which the living are nourished and the dead are buried without resentment is the beginning of the way of royal government. (Translation modified from Legge's in Chinese Classics, Vol. 2, p. 130 f. (1895.)

<sup>4</sup> See Carter, T. F. The Invention of Printing in China, 1925, ch. 10, etc.

for fully 4,000 years, while the Phoenicians long ago disappeared as a nation and as a people.

But knowledge and regulations for conservation were not enough to assure its lasting observance as a policy. Some of the reasons are set forth by the Senior author elsewhere.<sup>2</sup> Despite sound regulations certain forces brought on exploitation of lands and forests, which unleashed erosion and torrential floods that undermined the prosperity of extensive regions. It is not within the purposes of this paper to examine the causes for the failure and success of conservation policies and measures; its aim is rather to make known the record of a region in Shansi where policies for conservation waxed and waned through two cycles of several centuries.

The Chinese county or regional gazetteer is a remarkable historical source document. For more than 2,000 years it has been the custom in China to record

<sup>2</sup> *Loc. cit.*

important events; many records of geographical facts and conditions and of important personalities have for nearly a thousand years been included in printed volumes issued from time to time by counties, prefectures and provinces. Each later issue summarizes material from earlier issues and brings the record up to date with recent and new information. In these remarkable gazetteers are accounts of eclipses, of severe droughts and destructive floods, of forests and land use, besides other information. Such documents, of which the Library of Congress has one of the world's most complete collections now numbering more than 3,000 gazetteers besides duplicates, afford much information concerning the history of land use and its consequences in typical areas of China.

More than ever are we of America interested in China, for now she is one of our most powerful and resourceful allies in this world-wide war. Moreover, our movement for conservation in the United States was stimulated by studies of land use in that ancient country. We should also remember that with a cultivated

area of about two hundred million acres<sup>5</sup> China has for a long time been supporting a population of approximately 450 millions. Such effective use of land has not yet been approached in this country. Yet some have seen the danger that it will not continue in China without full use of conservation measures.<sup>6</sup>

President Theodore Roosevelt in a message to Congress in 1908 used China as an example of what happens when a country fails to preserve its forests, and pushed ahead the movement for conservation of forests in this country. Among other things he said :

All serious students of the question are aware of the great damage that has been done in the Mediterranean countries of Europe, Asia, and Africa by deforestation. The similar damage that has been done in Eastern Asia is less well known. A recent investigation into conditions in North China by Mr. Frank N. Meyer, of the Bureau of Plant Industry of the U. S. Department of Agriculture, has incidentally furnished

<sup>5</sup> According to statistics published by the Ministry of Agriculture and Commerce, for 1917, a maximum figure. *Ti chiu t'zu nung shang t'ung chi piao*, 1920.

<sup>6</sup> Tieh, T. Min, Soil Erosion in China, *Geog. Rev.*, 31: pp. 570-590, 1941.



SAWING UP LOGS INTO BOARDS

FOR PACKING DOWN THE MOUNTAIN TO THE TOWN OF TUNG CHAI IN THE PROVINCE OF SHANSI.

in very striking fashion proof of the ruin that comes from reckless deforestation of mountains, and of the further fact that damage once done may prove practically irreparable. So important are these investigations that I herewith attach as an appendix to my message certain photographs showing present conditions in China. They show in vivid fashion the appalling desolation, taking the shape of barren mountains and gravel and sand-covered plains, which immediately follows and depends upon the deforestation of the mountains.

. . . Each family, each community, where there is no common care exercised in the interest of all of them to prevent deforestation, finds its profit in the immediate use of the fuel which would otherwise be used by some other family or some other community. In the total absence of regulation of the matter in the interest of the whole people, each small group is inevitably pushed into a policy of destruction which can not afford to take thought for the morrow. . . . The forests can only be protected by the State, by the Nation; and the liberty of action of individuals must be conditioned upon what the State or Nation determines to be necessary for the common safety.

The lesson of deforestation in China is a lesson which mankind should have learned many times already from what has occurred in other places. Denudation leaves naked soil; then gullying cuts down to the bare rock; and meanwhile

the rock-waste buries the bottomlands. When the soil is gone, men must go; and the process does not take long.

This ruthless destruction of the forests in Northern China has brought about, or has aided in bringing about, desolation, . . . just as the destruction of the forests in Northern Africa helped towards the ruin of a region that was a fertile granary in Roman days. Short-sighted man, . . . when he has destroyed the forests, has rendered certain the ultimate destruction of the land itself. In Northern China the mountains are now such as are shown by the accompanying photographs,<sup>7</sup> absolutely barren peaks. Not only have the forests been destroyed, but because of their destruction the soil has been washed off the naked rock. The terrible consequence is that it is impossible now to undo the damage that has been done. . . . Almost all the rivers of Northern China have become uncontrollable, and very dangerous to dwellers along their banks, as a direct result of the destruction of the forests.

In the movement for conservation of natural resources which came after this message, though soil conservation was ably presented by Van Hise, Chamberlin and McGee, it was the idea of conserving

<sup>7</sup> Several of which are reproduced in this article.



CONTRAST VALLEY IN THE TUNG CHAI AREA

SO-CALLED BECAUSE A PORTION OF THE SLOPE WAS LEFT IN FOREST STAND AND THE REMAINDER CLEARED AND CULTIVATED. RUNOFF PLOTS WERE LOCATED IN THESE TWO AREAS TO SHOW CONTRAST IN RUNOFF AND EROSION UNDER THESE TWO CONDITIONS. LIGHTER COLORED AREAS ON THE CULTIVATED AREA SHOW EROSION PAVEMENT.

our forests that caught the public attention. Conservation of the soil, the basic resource, as a national policy essential to the general welfare had to wait for another generation and another Roosevelt as president.

Studies and experiments carried out by the Senior author on the ground in China<sup>8</sup> particularly in the provinces of Shansi, Shensi, Honan, Shantung, Anhwei, Chihli and Kiangsu, and research by the Junior author in Chinese historical records confirm the conclusions of the President's message, but with an important addition. Between deforestation and soil erosion with its far-reaching consequences of devastation is the process of cultivation to necessary crops. By this the soil formerly protected by its natural mantle of grass or forest is exposed to the dash of rain and blasts of wind to induce and speed up soil erosion. This erosion takes place at a rate faster

<sup>8</sup> Factors influencing the surface runoff of rain waters. Proc. Third Pan-Pacific Science Cong., Tokyo, pp. 2122-2148, 1926.

than soil formation and means land destruction in any land if not controlled.

That large areas in North China now treeless were formerly covered with forest, woods and grass is recorded in documents that come down to us from the past. Among the gazetteers or local, prefectoral and provincial histories in the Chinese collection of the Library of Congress there is ample evidence for extensive deforestation in the province of Shansi, as well as in other parts of China. The great Chinese Encyclopedia<sup>9</sup> confirms this evidence.

It has been asserted that the extensive areas covered with loess have never supported forests, on account of low water tables,<sup>10</sup> but the discoveries of J. G. Andersson in Honan Province seem to indi-

<sup>9</sup> Ku-chin t'u-shu chi-ch'eng, compiled from important earlier works and carefully edited by a staff of scholars under imperial order. Preface 1726.

<sup>10</sup> V. K. Ting, Prof. Granet's "La Civilization Chinoise," *Chinese Social and Pol. Sci. Rev.*, 15: 267, 1931.



VIEW OF A MOUNTAIN SLOPE ONCE COVERED WITH FORESTS

AND THEN CLEARED FOR CULTIVATION, IN THE TUNG CHAI AREA. THE STUMPS AND ROOTS GRUBBED OUT OF THE GROUND WERE PILED IN WINDROWS ON THE CONTOUR, FORMING A SORT OF TEMPORARY TERRACE. EROSION HAS WASHED OFF THE SOIL, LEAVING HEAVY EROSION PAVEMENT AT THE SURFACE. ISOLATED TREES LEFT STANDING GIVE AN IDEA OF THE ORIGINAL FOREST COVER.

cate a considerable growth of trees in parts of this area in the period before the present deep gullying had lowered water tables.<sup>11</sup> As to the present, Sowerby, who has traveled extensively in this region states that "over the loess hills of Shensi, where uncultivated areas occur, we find such small trees as the Hazel, the Birch, a small variety of Poplar and a stunted Oak growing in great profusion, and forming dense coverts for various kinds of game."<sup>12</sup> Cressey in speaking

A reasonable view is that zones of forest, brush and grass-land corresponded to rainfall belts as annual rainfall diminished toward the Gobi Desert, as studies of temple forests in extensive field surveys by the Senior author and Chinese associates have disclosed.<sup>14, 15</sup>

The process of forest removal and subsequent cultivation of the soil was observed by the Senior author in northern Shansi in Ning-wu Prefecture, near the sources of the Fen River. The effects of this combined process were also observed in eroded slopes and boulder-strewn dry stream beds, that became raging debris-laden torrents after heavy rains. Population pressure on land had pushed the cultivation line higher and higher up slopes where farming means more and more work. Following clearing of natural growth for cultivation, soil erosion develops gullies in the loess to astounding depths, often to the depth of the loessial mantle of several hundred feet, whereas erosion in residual soils washes away fine particles leaving behind rock fragments to form erosion pavement. Gullies may later cut through the erosion pavement to bed rock and fill the stream channel with gravel, cobble and boulders.

Ning-wu Prefecture, one of the study areas (now Ning-wu District) lies in the northwestern part of Shansi Province, about the headwaters of the Fen and Sang-kan Rivers. The topography is rough and mountainous with a little plateau land. The rainfall is in general convectional, occurring mostly as heavy downpours in summer. A mantle of loessial soil covers gently sloping land and lower flanks of the mountains. Wherever the loess occurs it has been cleared by eager farmers for cultivation. Above the loess mantle residual, noncalcareous



#### FOREST DENUDATION

SHOWING IN THE TUNG CHAI AREA HOW FORESTS WERE CUT AND THE LAND CLEARED FOR CULTIVATION, UNLEASHING TORRENTIAL RUNOFFS WHICH CUT GULLIES THROUGH THE LOWER SLOPES.

of the region of the loess highlands, says, "Much of the highlands, except perhaps the desert margins, appears to have once been covered with a continuous forest."<sup>13</sup>

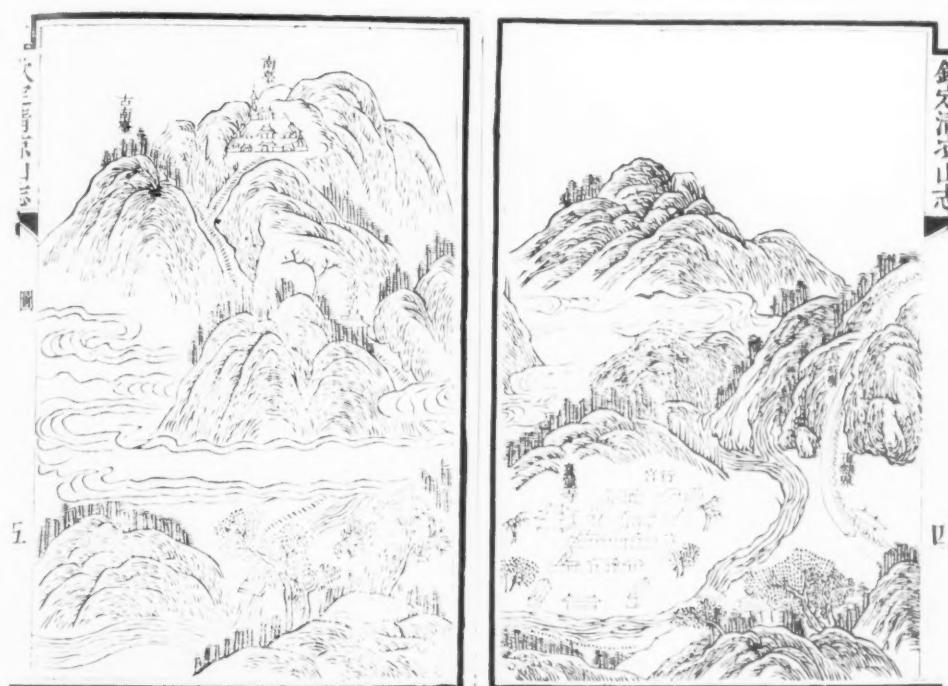
<sup>11</sup> Andersson, J. G., Children of the Yellow Earth, 1934, Chap. 10; Essays on the Cenozoic of Northern China. Memoirs of the Geol. Survey of China, Ser. A, No. 3, Mar. 1923, p. 141.

<sup>12</sup> Sowerby, A. de C. Sport and Science on the Sino-Mongolian Frontier, 1918, p. 221.

<sup>13</sup> Cressey, Geo. B., China's Geographic Foundations, 1934, p. 199.

<sup>14</sup> Lowdermilk, W. C., Forest destruction and slope denudation in the Province of Shansi, *China Jour. of Sci. and Arts*, 4: 127-135, 1926.

<sup>15</sup> Lowdermilk, W. C., T. I. Lee and C. T. Ren, A Cover and erosion survey of the Hwai River Catchment Area. In Chinese, Nanking, 1926: Ms. in English, S.C.S. Washington.



*Library of Congress*

OLD CHINESE ILLUSTRATIONS FROM OFFICIAL GAZETTEER  
PRESENTED TO THE EMPEROR IN A.D. 1786. THIS VIEW SHOWS THE SOUTHERN PLATFORM OF  
WU-T'AI SHAN AND ELEVATIONS TO THE SOUTHEAST, WITH FOREST REMNANTS.



*Bailey Willis*

BED OF THE T'AI-SHAN HO AT JUNCTION OF A TRIBUTARY  
SHOWING DEPOSITED DETRITUS, BARED HILLS AND A VILLAGE WITH SOME CULTIVATION TERRACES  
IN LOESS DRIFT, MUCH OF WHICH HAS WASHED OFF THESE SLOPES.

gray brown podzolic soils mantle upper slopes and table lands of the mountains which were originally covered by excellent forest stands from pines at lower to spruce-larch at higher elevations.

The senior author found extensive forest remnants on mountains in the western part of the area, west of Tung Chai. On other slopes isolated forest trees

reproduction of the trees was taking place, showing that conditions of climate and soil were still favorable to forest growth. The gazetteer of Ning-wu Prefecture of 1750 includes a record taken from a stone monument then preserved, dated in 1684, recording successful effort in preventing the opening of certain mountains in the prefecture for the removal of trees, stated to be mostly birch, willow and others suitable for rafters, large size timber (pine) then being very scarce. It also records that in the period 1573-1620 Provincial Governor Lü K'un ordered that in all the mountain valleys along the border, trees should be planted as an obstacle to inroads of enemies on horseback, and prohibited cutting them down. But by 1750 only a few were said to remain. The advance of cultivation upon the forest was observed and reported by the senior author in 1925.<sup>14</sup> That the clearing of forest in this region was done mainly for the purpose of cultivating the soil was made clear by thousands of cubic feet of timber that were left to rot beside the newly cleared fields.

Experiments were made to determine the percentage of runoff, the amount of erosion, from duplicated plots in temple forests and in fields on adjacent slopes denuded by erosion. Results of these field experiments at three widely spaced centers are given in full elsewhere.<sup>15</sup> Out of five storms measured at the Tung Chai study area, runoff occurred during only two storms from plots in a temple forest, averaging for all storms 0.013 per cent. of total rainfall; whereas runoff occurred in all storms on plots in fields denuded by erosion, where the average was 2.27 per cent., and the greatest runoff coefficient for any one storm was 6.64 per cent. Immediate storm runoff was influenced by rate of rainfall, slope and character of the soil. This evidence readily ex-



IN SHANSI PROVINCE

IN THE TUNG CHAI AREA. VIEW OF FORMERLY FORESTED SLOPES WHICH WERE CULTIVATED AND SERIOUSLY ERODED. TORRENTIAL RUNOFF FROM ERODING SLOPES, TO BE NOTED IN THE BACKGROUND, HAS CREATED A ROCKY, TORRENT-TORN VALLEY, AS SEEN IN THE FOREGROUND.

showed where forests had formerly stood. Here and elsewhere in Shansi were found forest remnants where temples and monasteries had protected forest areas ranging from a few to many hundreds of acres. In these forest remnants natural

<sup>14</sup> *Loc. cit.*

<sup>15</sup> Lowdermilk, W. C. Factors influencing the surface runoff of rain waters. Third Pan-Pacific Science Congress. Tokyo, 1926, pp. 2122-2148.



Bailey Willis

LOOKING UP THE AGGRADED VALLEY OF THE T'AI-SHAN HO  
TO WESTERN PLATFORM OF WU-T'AI SHAN. ALLUVIAL CONE IS FROM A TRIBUTARY ON THE LEFT.



*Library of Congress*

CENTRAL PLATFORM OF WU-T'AI SHAN  
FROM THE SAME GAZETTEER. NOTE CONSIDERABLE REMNANTS OF FOREST REPRESENTED.



*Bailey Willis*

VALLEY OF THE T'AI-SHAN HO  
WITH ALLUVIAL FAN FROM A TRIBUTARY. WU-T'AI SHAN VILLAGE WITH SLOPES TERRACED TO  
RETAIN THE SOIL IS AT THE LEFT.

plained why cultivated slopes were yielding torrential storm runoff and were eroding into deep and destructive gullies during each rainy season, whereas no measurable erosion was taking place within temple forests, and storm runoff was very low and clear.

In the Tung Chai region, fields that had been cultivated for from 3 to 9 years varying with slope were abandoned for cultivation and thereupon herds of sheep and goats were turned out on them. Return of vegetation under heavy grazing was slow, and left the land exposed to erosion each rainy season.

We pass now to an area less than fifty miles to the east of Tung Chai, for which we made a study on the basis of unusually full records in gazetteers.<sup>17</sup>

#### THE SACRED MOUNTAIN OF WU-T'AI SHAN

The region of Wu-t'ai Shan is very mountainous, with high rounded summits and lower areas much dissected by erosion. The Hu-t'o River flows on three sides of and with its affluents drains the Wu-t'ai massif. Another mountain ridge extends along the Great Wall to the north and northwest, with the nar-



Bailey Willis

VIEW FROM SUMMIT OF SOUTHERN PLATFORM OF WU-T'AI SHAN.  
DEFORESTED SLOPES CUT WITH GULLIES COMPRIZE MOST OF THE LAND SURFACE.

The gazetteer of Ning-wu Prefecture already cited has a record dated in 1750 of school and sacrificial lands that tells of decrease in income from sloping lands that became wastes. The Supplement dated in 1857 records on the first page that the Sang-kan River changed its course and washed away a hill near the East Gate of the City of Ning-wu.

Thus from observation and experiment, confirmed by a study of official records is revealed the process by which lands in this part of Shansi formerly covered with forest are cleared, cultivated, grazed, lose their productiveness and become a source of torrential floods.

row plain of the Hu-t'o between. Rainfall of the summer rainy season is prevailingly convectional, but there is also some winter snowfall on the mountains.

Soils of the Wu-t'ai Shan region are similar to those of the Tung Chai area—being loessial on the lower flanks of the mountain and residual on the upper slopes and summits, chiefly from igneous rock. From Fig. 15 one may see how the loess occurs as drifts on the lower slopes. These soil drifts are generally sought out for farming, often terraced to save the

<sup>17</sup> Lowdermilk, W. C. and Wickes, D. R., History of Soil Use in the Wu T'ai Shan Area, a monograph issued under the auspices of the N. C. Branch of the Royal Asiatic Soc., 1938.

soil from erosion. Residual soils being thinner and containing rock fragments are not suited to terracing. Clearing and cultivation induces erosion that soon washes off fine soil and leaves an erosion pavement at the surface. Abandonment follows after a few years of cultivation. Accelerated runoff from eroded upper slopes has cut down through drifts of loessial soil and has washed much of it away, except where safeguarded by bench terracing.

exception of the highest summits. The region was sparsely settled in the first century of the Christian era; it became a favorite retreat for those seeking retirement from the world. Numerous monasteries were founded in the seclusion of these mountains in which monks supported themselves by farming. Settlers besides the monks followed and also cleared land for cultivation, as stated by a contemporary writer about the year A.D. 1087.<sup>18</sup> In the early part of the



Bailey Willis

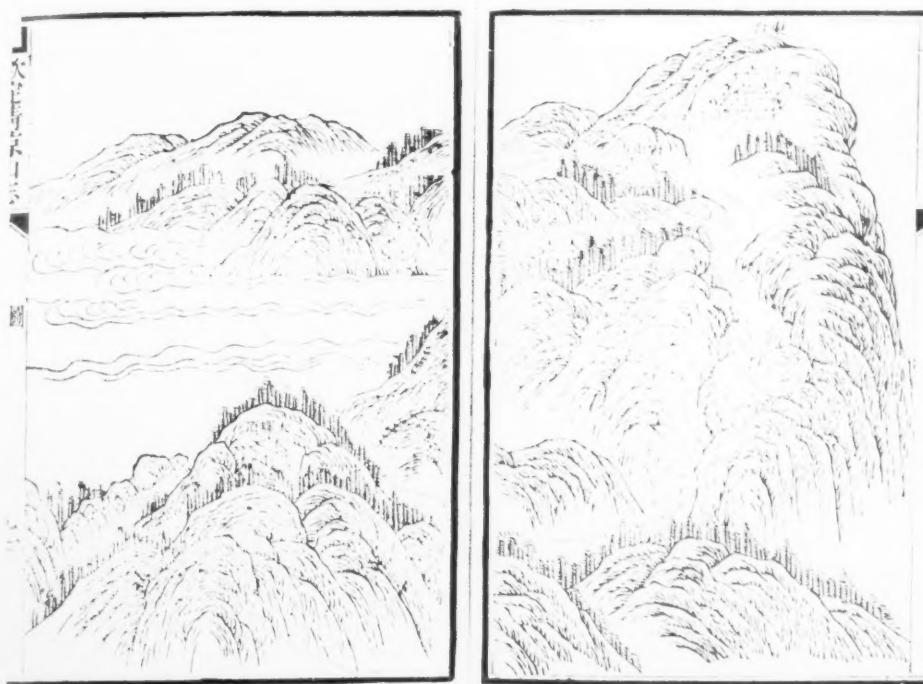
A GRAPHIC PICTURE OF THE EFFECTS OF EROSION  
AS A RESULT OF DEFORESTATION AND CULTIVATION, HIGH ON THE NORTHWEST SLOPE OF WU-T'AI SHAN. SOIL HAS BEEN WASHED OFF TO BARE ROCK IN THE FOREGROUND.

Records of this area are preserved in three gazetteers of the mountain region, which covers about 800 square miles or about 500,000 acres. Likewise records exist for two districts and the department in which the mountain of "five platforms" lies. These gazetteers date from A.D. 1596, 1701, 1777, 1785, 1786, 1836, 1881, 1882, and contain much information bearing on our subject.<sup>17</sup>

From these records we learn that dense high forests once covered the entire region of the mountain massif including adjoining ranges, on an area estimated at 3,000 square miles, with the probable

Ming Dynasty, which lasted from 1368 to 1644, we are assured that the old forested condition still prevailed. By the year 1580, about 200 years later, much of this forest had been cut and sold for profit from timber. An official, Hu Lai-kung, visiting the mountain in that year was struck with the desolation he saw. As a result he had a special report made to the Throne, that led to a prohibition by the Emperor of cutting timber in these mountains. The text of this report has been preserved to us in gazetteers of

<sup>18</sup> Chang Shang-ying, who was at Wu-t'ai in that year. *Id. p. 3.*



*Library of Congress*

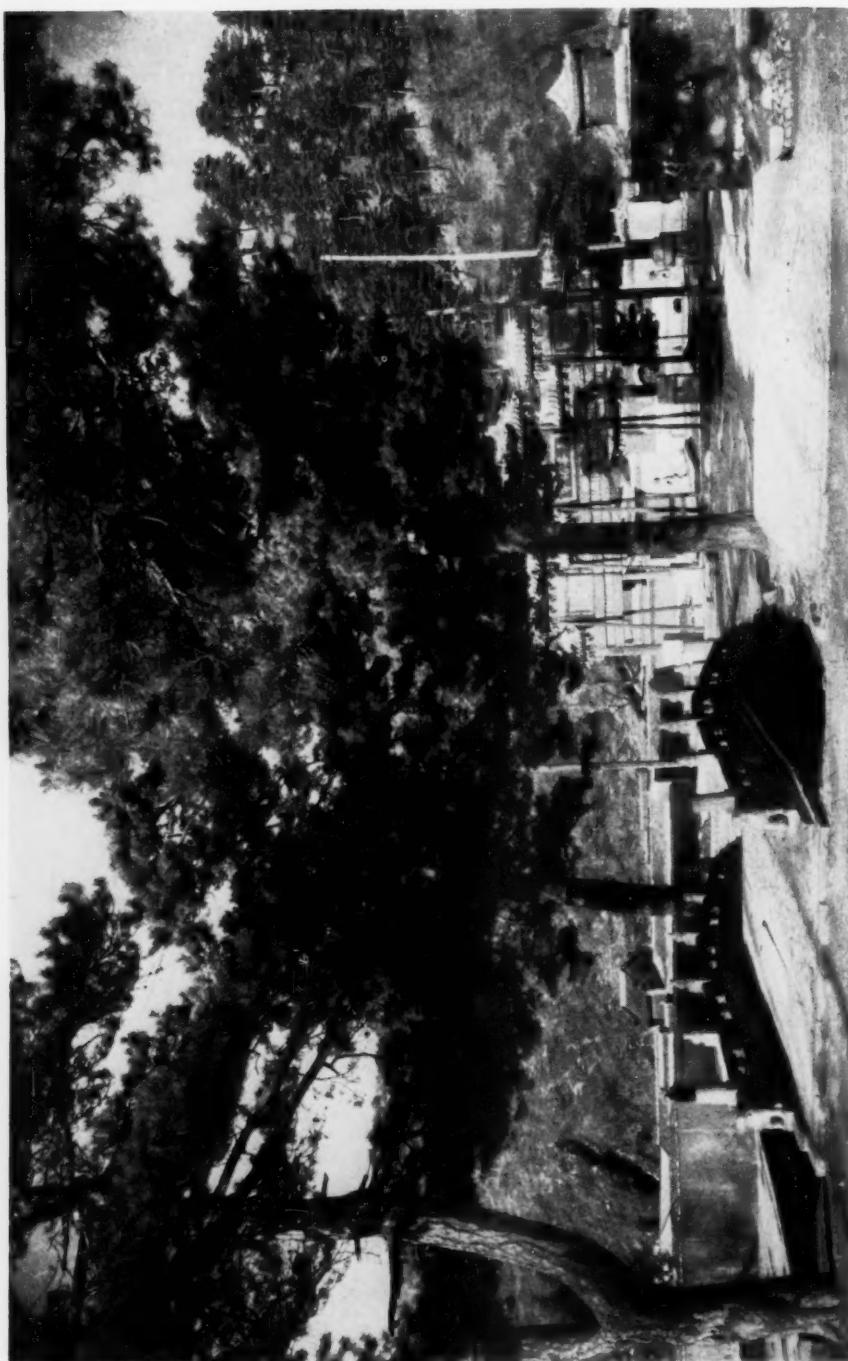
EASTERN PLATFORM OF WU-T'AI SHAN  
AND ADJACENT HEIGHTS, WITH FOREST REMNANTS, FROM THE SAME GAZETTEER.



*Bailey Willis*

TERRACES MADE IN DRIFTS OF LOESS

FOR RETAINING SOIL ON SLOPES OF MOUNTAINS WHICH ARE BARE OF FOREST, EIGHT MILES SOUTHEAST OF WU-T'AI HSIEN. BY SUCH TERRACING THE LOESS, WHICH ALONE IS CULTIVATED, IS PROTECTED FROM EROSION.



PINES PRESERVED NEAR A MONASTERY

IN THE WU-T'AI SHAN AREA NEAR THE CLEAR WATER RIVER, ABOUT TEN MILES EAST OF THE SOUTHERN PLATFORM.

the mountain. The chief argument presented for prohibition of cutting and for preservation of the forest is that this forest was important for defense against invasions of nomads from the north. This special report of 1580 to the Throne presented by the Censor Kao Wen-chien states:

In Shansi the border between China and the land of the barbarians is a mountain range. Fortunately, the forests between Pei-lou and Ning-wu are flourishing and thick, serving as a fortification for defense, and the mountain of Wu-t'ai with its numerous ridges and dense for-

driving out of unregistered wood cutters from neighboring districts, patrol of the forests day and night by monks and officials with archers to support them, arrest and speedy trial of offenders. No timber old or newly cut was allowed to be sold, the local official to be held responsible for any log reaching a river or stream. "Thus," the report concludes, "with everyone doing his duty, the national frontier will be safeguarded forever."

Recommendations of the special report



Bailey Willis

BARED AND FORMERLY CULTIVATED MOUNTAIN SLOPES  
IN THE PROCESS OF DISSECTION INTO GULLIES, WU-T'AI SHAN AREA.

ests was relied on as an inner barrier. The fathers handed down the tradition which says that the trees of the two mountain ranges formerly met in green obscurity for a thousand li (330 miles) and even if the horses of the northern barbarians broke through, they could not proceed at a gallop.<sup>19</sup>

Methods recommended and then ordered to be carried out for the protection of forest on Wu-t'ai Shan included the

<sup>19</sup> Lowdermilk and Wickes, History of Soil Use in the Wu T'ai Shan Area, p. 7, 1938. The idea of forests aiding defense was put forward by Ch'iu Chun, a Grand Secretary, in a work presented to the emperor in 1488. Ta-hsueh yen-i pu, ch. 150, 3a f.

were approved by the Emperor, the Board of War taking cognizance, and the proposals were authorized to be carried out. It is recorded that the cutting and logging were stopped. Not only so, but the official gazetteer of 1786 contains the statement that from the time of this prohibition of felling (about 1580) new growth gradually came back, as was to be expected if the ground was not cultivated. Other passages in the gazetteers referring to forest growth confirm this statement.

It seems clear that forests covered the area from which timber cutters had



Bailey Willis

## F FARMS IN THE PATH OF FLOODS

IN A LOESS BASIN, WU-T'AI SHAN AREA, SHOWING DEPOSITS OF DEBRIS FROM FLOODS AND WALLS BUILT BY FARMERS TO CATCH SILT TO BUILD OF NEW LAND OUT OF THE WASTE OF ERODED SLOPES.



Bailey Willis

## DEFORESTED AND GULLIED SLOPES OF A CANYON

ON THE NORTH SLOPE OF WU-T'AI SHAN. TERRACES FOR CULTIVATION CAN BE SEEN HIGH ON THE SLOPES AT THE LEFT AND IN THE MIDDLE DISTANCE.

been expelled by imperial order. At the time of the first general deforestation the evidence favors the view that no general cultivation of soils took place. The official report refers to timber cutters as people without root (in the soil) who do not follow agriculture. And the references to the return of forests make it improbable that serious soil erosion had taken place at that period. However, from the year 1657, only seventy-seven years following the prohibition of cutting, we begin to find in the gazetteers reports of colonists of this region being encouraged to bring new land under cultivation and of additions to the cultivated area in Tai Department (including Fan-chih, Kuo, and Wu-t'ai Districts) of which these mountains occupied a considerable part. This increase of cultivation at the higher elevations in the mountains occurs probably after introductions of New World crops of Irish potatoes and maize adapted to higher altitudes than former Chinese crops.<sup>20</sup> The official gazetteer of Wu-t'ai Shan presented to the Emperor Ch'ien-lung in 1786, along with the statement that the mountain for a hundred years had been well wooded and green as of old, also reports progress of cultivation, stating that cultivating and planting were daily opening up more land. The gazetteer of the department for 1785 confirms wide extension of cultivation in Wu-t'ai. Between 1656 and 1759 records indicate the cultivation of a total of at least 8,560 acres previously uncultivated in the two districts which include Wu-t'ai Shan.

That destructive erosion followed the cultivation of slopes is shown by records of school lands in the gazetteer of Wu-t'ai District for 1777. It notes that certain "school fields of the District being mountain fields are changed to waste; formerly over thirty ch'ing,<sup>21</sup> they now are only something over two ch'ing"; and not far away 35.5 ch'ing of school fields, including a strip of lofty pine, are reported as "now abandoned."



Bailey Willis  
DENUDED SLOPES  
ON THE NORTHERN SIDE OF WU-T'AI SHAN.

Population figures for these districts also indicate a great increase in the number of people supported, presumably for the most part by agriculture. For the northern district, the population reported for the Ch'ien-lung period two centuries later (1736-1795) is more than fifteen times that in Chia-ching time (1553), the increase being 73,000. In the southern district the increase over

<sup>20</sup> David, A., *Journal de mon troisième Voyage d'exploration dans l'empire Chinois*. Vol. 1, pp. 181, 188. 1875.

Maize, known in China before 1570, was reported much grown in Shansi before 1643. B. Laufer, *Congrès Intern. des Américanistes*, XV. Quebec, 1907, pp. 238 f., 251. Potatoes were a later introduction, apparently by 1700, and their planting received imperial encouragement in 1752. B. Laufer, *The American Plant Migration*, Part I, pp. 71 f. 1938.

<sup>21</sup> A ch'ing is 100 mou, or 15.13 acres; 30 ch'ing are about 454 acres.



Bailey Willis

## TREES PRESERVED BY A VILLAGE AND ITS SHRINE

WITH DENUDED MOUNTAINS AND GULLIES IN LOESS NEAR BY, IN THE WU-T'AI SHAN AREA. THE LOESS ON THE LOWER SLOPES HAS BEEN TERRACED FOR CULTIVATION; IT HAS PROBABLY BEEN WASHED OFF FROM THE STEEPER SLOPES.

about 400 years, from Ming Hung-wu time (A.D. 1368-1398) to the reign of Ch'ien-lung (1736-1795) is 77,424, making the total population reported five times as large as before. Even allowing for inaccuracies in reporting, it seems clear that a notable increase in population took place in the Wu-t'ai Shan area following this period of clearing and cultivation. Some people probably worked at coal mines, quarries, and lime kilns, which are reported in the gazetteers, and some doubtless were wood-cutters and charcoal burners.

To the destruction of forests was added the cultivation of large areas of sloping lands. A later prohibition of the cutting of mountain timber decreed in 1683 on the occasion of a visit to the Wu-t'ai Shan by the Emperor K'ang-hsi seems not to have prevented the continued clearing of land for cultivation. And by the year 1904 Bailey Willis of the U. S. Geological Survey on visiting the Sacred Mountain, recorded<sup>22</sup> that the

forests had been completely destroyed, as E. Lieent also reported<sup>23</sup> in 1914. A few monasteries still preserved groves about them, and under the summits scattered pine trees still grew on the slopes. Horse dung was burned for heating in all the region for want of fuel wood. Crops of potatoes, an introduction from the Western Hemisphere, and hemp were raised. High summits bore cultivated fields on their slopes. By this time slopes and ravine bottoms of the massif of Wu-t'ai were absolutely denuded by wood cutters and herders. Southwest of the Wu-t'ai massif, between it and the city of Wu-t'ai Hsien, he reported the medium heights entirely denuded, and southwest of the city he again speaks of black, denuded mountains.<sup>23</sup>

Both Willis and Lieent tell of great alluvial cones of shingle, gravel and clay, the wash of rock and residual soil on the mountain slopes, such as the Senior au-

<sup>22</sup> Willis, Bailey, *et al.* Research in China, 1907, Vol. I, p. 209.

<sup>23</sup> Lieent, E. Comptes Rendus de Dix Années (1914-1923) de Séjour et d'Exploration dans le Bassin du Fleuve Jaune . . . 1924, pp. 1466, 1467, 1461.



Bailey Willis

## ERODED LOESS AND DEPOSITED DETRITUS

AT THE FOOT OF BARE MOUNTAINS, EIGHTEEN MILES NORTHEAST OF WU-T'AI HSIEH AND FIVE MILES WEST OF THE SOUTHERN PLATFORM, DRIFTS OF LOESS HAVE PERSISTED ON THE GENTLER SLOPES OF THE MOUNTAINS; IT HAS DOUBTLESS BEEN WASHED OFF STEEPER SLOPES.

thor also recorded in the Tung Chai area just to the West. Emil S. Fischer, who visited the mountains in 1923 reported,<sup>24</sup> besides the general bareness of trees, extensive grazing over the mountain range, "herds of sheep, horses, cattle and goats at times over 500 heads strong, grazing on the slopes"; also "numerous camel herds grazing as well as hundreds of horses." At one place he reports that "the men were to be seen toiling on the mountain sides wherever there was a spot that permitted cultivation." Cutting of forests followed by erosion of cultivated fields had denuded the Sacred Mountain of Wu-t'ai shan.

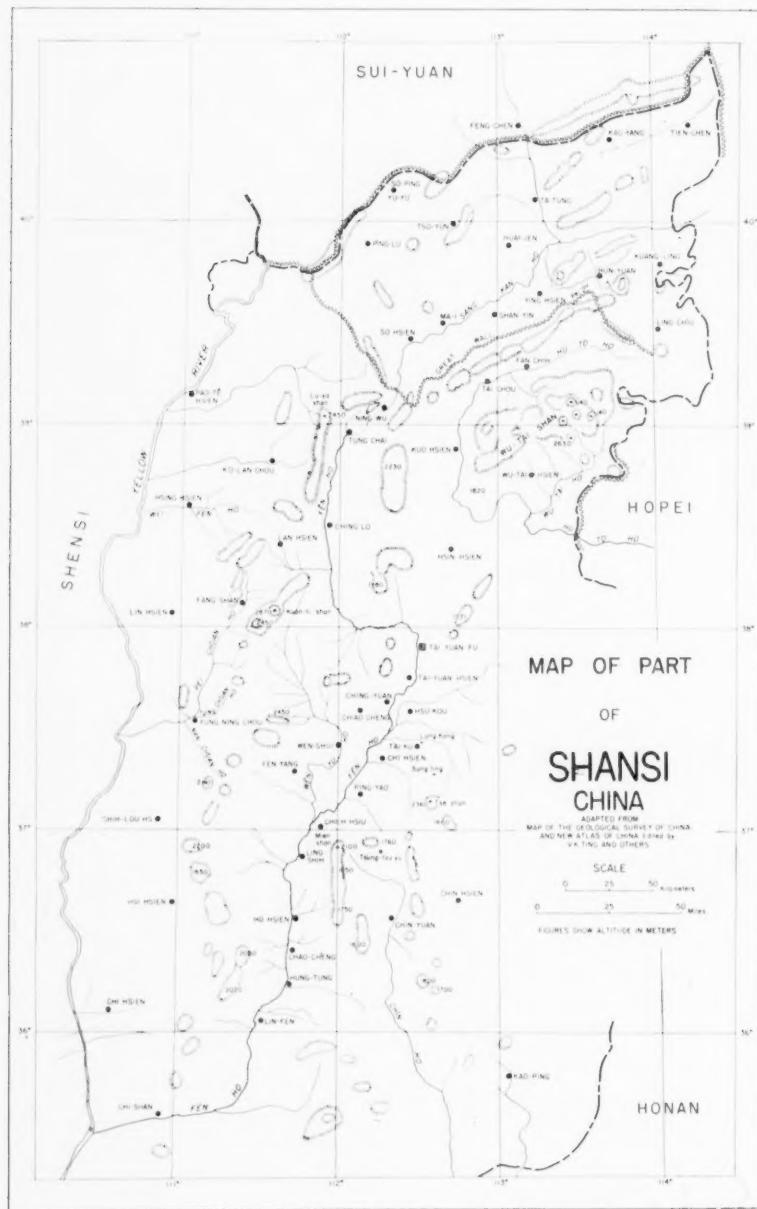
#### RECORDS OF FLOODS FROM ANCIENT TIMES

As early as the 4th year of T'ai-ting, in A.D. 1327 (the Yuan Dynasty) we find a record of destructive floods in the Hu-t'o River, which carries most of the

drainage from Wu-t'ai Shan, flowing around the mountain group on three sides and eastward into Hopei Province, and at Hsien Hsien unites with the Chin-yang River to form the Tzu-ya River, a tributary of the Hai Ho that flows by Tientsin. In the period from A.D. 1056 to 1063 (Chia-yu hsi-ning time of the Sung Dynasty) a western tributary of the Hu-t'o, the Yang-wu River, is stated in the local gazetteer to have frequently ruined cultivated land along its banks by its floods, so that some land was abandoned.

In a later period it is recorded in the gazetteer of Fan-chih District, which includes the northern part of Wu-t'ai Shan (1836), "mountain streams often overflow, quickly swell and quickly dry up"; and of irrigation canals of the Hu-t'o River the same gazetteer says: "The water of this river is rapid from its source to where it leaves the district; and when the fierce overflow of mountain streams occurs, it no sooner swells than it dries up." A torrential regime of

<sup>24</sup> Fischer, E. S., Jour. of the N. China Branch of the Royal Asiatic Soc. Vol. 54 (1923) pp. 81-113.



flooding and drying up is indicated in other statements of the same gazetteer. This river also repeatedly changed its course, owing to deposits of erosion debris in its channel, as did its tributaries. Irrigation was thus made precarious, and great damage was done to agricultural land and settlements.

#### LAND IS RUINED AND ABANDONED

Again and again from A.D. 1647 on, we find records of the acreage of lands exempted from taxation as waste or abandoned; of these some are doubtless due to losses of soil by erosion and some to ruin by the overflow of streams. In the 4th year of Shun-chih (1647) an edict ex-

empted 5,189 acres (343 ch'ing) of ownerless deserted land. In 1657 another edict exempted a total of 34,870 acres of deserted land of the Fan-chih district, of which 13,186 acres were agricultural land of civilians. Abandoned land was characterized as "injured and perished"; 20,877 acres were deserted land of military colonists. In Wu-t'ai District in 1657, 16,806 acres of injured and destroyed waste land of civilian owners were exempted by edict. Remaining land actually cultivated was only 22,809 acres (1,507.5 ch'ing, of which 4.5 ch'ing are listed as water land, 316.6 as level land, 879.7 as slope land, and 306.6 as sandy land). In 1652 there were exempted 358 acres of deserted land of military colonists. In Tai Department<sup>25</sup> adjoining Fan-chih District on the west, it is recorded that at various times from 1785 (50th year of Ch'ien-lung) to 1879 (5th year of Kuang-hsu) there were removed from the tax list deserted agricultural lands of civilians and colonists to the amount of about 15,465 acres, nearly one sixth of the total taxable land. In 1880 land in the neighborhood of Shê-ying, long deserted on account of a flood in 1785 which deposited stones and deep sand upon it or washed it away, to the total of about 1,189 acres was permanently released from taxation. In Kuo District, on the west side of Wu-t'ai Shan, in 1787, 1803, and 1880 a total of about 2,236 acres found by investigation to have been swallowed up by the river, ruined by erosion, or covered with stones, were exempted by edict from taxation.

Thus a large mountainous area formerly forested, despite repeated and for-

<sup>25</sup> Exclusive of Wu-t'ai, Fan-chih and Kuo Districts.

a time apparently successful efforts to conserve forests, was cleared of timber and largely cultivated, with consequent destructive erosion. Abandonment of land for cultivation totaled nearly 75,000 acres;<sup>26</sup> violent and destructive floods and changes in their courses on the part of drainage streams also followed.

The Districts of Hun-yuan and Ling-ch'iü adjoin this area on the northeast, and their records reveal similar conditions. One gazetteer dated in 1652 states that a magistrate in the period of Ch'eng-hua, 1465-1487, secured the relaxing of a former prohibition of cutting or gathering firewood on Heng Shan Mountain, south of the city of Hun-yuan, that reveals an early measure for protection of forests. Toward the north and west of these districts extended Ta-t'ung and So-p'ing Prefectures, which have records of former forests with remnants on mountains, of extensive colonization, of the abandonment of large quantities of land formerly cultivated, and of torrential floods and shifts in stream courses.

A supplementary gazetteer issued in 1881, in a record of the virtuous government of Yen Ch'ing-Yun the magistrate of Hun-yuan Department in 1771-1782, tells of his introducing potatoes (Irish) from Shensi, his native province, and of extensive plantings with great success in keeping great numbers of people alive during famines of 1787, 1832 and 1836. Growing of potatoes and maize may have been the occasion for cultivating so much of the forested soils of the higher slopes that induced destructive erosion and torrential debris-laden storm runoff.

<sup>26</sup> Lowdermilk and Wiekes, History of Soil Use in Wu T'ai Shan Area, p. 23.

(To be Concluded)

## GREGOR MENDEL AND HIS WORK

By Dr. HUGO ILTIS

PROFESSOR OF BIOLOGY, MARY WASHINGTON COLLEGE

IT is 120 years since, in a small village on the northern border of what was called Austria at that time, a boy was born in a farmer's house who was destined to influence human thoughts and science. Germans, Czechs and Poles had been settled side by side in this part of the country, quarreling sometimes, but mixing their blood continually. During the Middle Ages the Mongolic Tatars invaded Europe just there. Thus, the place had been a melting pot of nations and races and, like America, had brought up finally a splendid alloy. The father's name was Anton Mendel; the boy was christened Johann. He grew up like other farmers' boys; he liked to help his father with his fruit trees and bees and retained from these early experiences his fondness for gardening and bee-keeping until his last years. Since his parents, although not poor compared with the neighbors, had no liquid resources, the young and gifted boy had to fight his way through high school and junior college (*Gymnasium*). Finally he came to the conclusion, as he wrote in his autobiography, "That it had become impossible for him to continue such strenuous exertions. It was incumbent on him to enter a profession in which he would be spared perpetual anxiety about a means of livelihood. His private circumstances determined his choice of profession." So he entered as a novice the rich and beautiful monastery of the Augustinians of Bruenn in 1843 and assumed the monastic name of Gregor. Here he found the necessary means, leisure and good company. Here during the period from 1843 to 1865 he grew to become the great investigator whose name is known to every schoolboy to-day.

On a clear cold evening in February, 1865, several men were walking through the streets of Bruenn towards the modern school, a big building still new. One of those men, stocky and rather corpulent, friendly of countenance, with a high forehead and piercing blue eyes, wearing a tall hat, a long black coat and trousers tucked in top boots, was carrying a manuscript under his arm. This was Pater Gregor Mendel, a professor at the modern school, and with his friends he was going to a meeting of the Society of Natural Science where he was to read a paper on "Experiments in Plant Hybridization." In the schoolroom, where the meeting was to be held, about forty persons had gathered, many of them able or even outstanding scientists. For about one hour Mendel read from his manuscript an account of the results of his experiments in hybridization of the edible pea, which had occupied him during the preceding eight years.

Mendel's predecessors failed in their experiments on heredity because they directed their attention to the behavior of the type of the species or races as a whole, instead of contenting themselves with one or two clear-cut characters. The new thing about Mendel's method was that he had confined himself to studying the effects of hybridization upon single particular characters, and that he didn't take, as his predecessors had done, only a summary view upon a whole generation of hybrids, but examined each individual plant separately.

The experiments, the laws derived from these experiments, and the splendid explanation given to them by Mendel are to-day not only the base of the modern science of genetics, but belong to the

PORTRAIT OF GREGOR MENDEL BY JOSEPH O. FLATTER<sup>1</sup>

fundamentals of biology taught to millions of students in all parts of the world.

Mendel had been since 1843 one of the brethren of the beautiful and wealthy monastery of the Augustinians of Bruenn, at that time in Austria, later in Czechoslovakia. His profession left him sufficient time, and the large garden of the monastery provided space enough, for his plant hybridizations. During the eight years from 1856 to 1864, he observed with a rare patience and perseverance more than 10,000 specimens.

<sup>1</sup> I am indebted to Professor William Luther McDermott for the photographs in this article.

In hybridization the pollen from the male plant is dusted on the pistils of the female plant through which it fertilizes the ovules. Both the pollen and the ovules in the pistils carry hereditary characters which may be alike in the two parents or partly or entirely different. The peas used by Mendel for hybridization differed in the simplest case only by one character or, better still, by a pair of characters; for instance, by the color of the flowers, which was red on one parental plant and white on the other; or by the shape of the seeds, which were smooth in one case and wrinkled in the



MENDEL'S BIRTHPLACE IN HEINZENDORF, AUSTRIA

other; or by the color of the cotyledons, which were yellow in one pea and green in the other, etc. Mendel's experiments show in all cases the result that all individuals of the first generation of hybrids, the  $F_1$  generation as it is called to-day, are uniform in appearance, and that moreover only one of the two parental characters, the stronger or the dominant one, is shown. That means, for instance, that the red color of the flowers, the smooth shape of the seeds or the yellow color of the cotyledons is in evidence while the other, or recessive, character seems to have disappeared. From the behavior of the hybrids of the  $F_1$  generation, Mendel derived the first of the experimental laws, the so-called "Law of Uniformity," which is that all individuals of the first hybrid generation are equal or uniform. The special kind of inheritance shown by the prevalence of the dominant characters in the first hybrid generation is called alternative inheritance or the pea type of inheritance. In other instances, however, the hybrids show a mixture of the parental characteristics. Thus, crossing between a red-flowered and a white-flowered four o'clock (*Mirabilis*) gives a pink-flowered  $F_1$  generation. This type of inheritance is called the intermediate, or *Mirabilis*, type of inheritance.

Now, Mendel self-fertilized the hybrids

of the first generation, dusting the pistils of the flowers with their own pollen and obtained thus the second, or  $F_2$ , generation of hybrids. In this generation the recessive characters, which had seemingly disappeared, but, which were really only covered in the  $F_1$  generation, reappeared again and in a characteristic and constant proportion. Among the  $F_2$  hybrids he found three red-flowered plants and one white-flowered plant, or three smooth-seeded and one-wrinkled-seeded plant, or three plants with yellow cotyledons and one with green ones. In general, the hybrids of the  $F_2$  generation showed a ratio of three dominant to one recessive plants. Mendel derived from the behavior of the  $F_2$  generation his second experimental law, the so-called "Law of Segregation." Of course, the characteristic ratio of three dominant to one recessive may be expected only if the numbers of individuals are large, the Mendelian laws being so-called statistical laws or laws valid for large numbers only.

The third important experimental law Mendel discovered by crossing two plants which distinguished themselves not only by one but by two or more pairs of hereditary characters. He crossed, for instance, a pea plant with smooth and yellow seeds with another having green and wrinkled seeds. The first, or  $F_1$ ,

generation of hybrids was of course uniform, showing both smooth and yellow seeds, the dominant characters.  $F_1$  hybrids were then self-fertilized and the second hybrid, or  $F_2$ , generation was yielded in large numbers, showing all possible combinations of the parental characters in characteristic ratios and that there were nine smooth yellow to three smooth green to three wrinkled yellow to one wrinkled green. From these so-called polyhybrid crossings, Mendel derived the third and last of his experimental laws, the "Law of Independent Assortment."

These experiments and observations Mendel reviewed in his lecture. Mendel's hearers, who were personally attached to the lecturer as well as appreciating him for his original observations in various fields of natural science, listened with respect but also with astonishment to his account of the invariable numerical ratios among the hybrids, unheard of in those days. Mendel concluded his first lecture and announced a second one at the next month's meeting and

promised he would give them the theory he had elaborated in order to explain the behavior of the hybrids.

There was a goodly audience, once more, at the next month's meeting. It must be admitted, however, that the attention of most of the hearers was inclined to wander when the lecturer became engaged in a rather difficult algebraical deduction. And probably not a soul among the audience really understood what Mendel was driving at. His main idea was that the living individual might be regarded as composed of distinct hereditary characters, which are transmitted by distinct invisible hereditary factors—to-day we call them genes. In the hybrid the different parental genes are combined. But when the sex cells of the hybrids are formed the two parental genes separate again, remaining quite unchanged and pure, each sex cell containing only one of the two genes of one pair. We call this fundamental theoretical law the "Law of the Purity of the Gametes." Through combination of the different kinds of sex cells, which



BRUENN, CZECHOSLOVAKIA, WHERE MENDEL LIVED

BRUENN IS SITUATED BELOW THE SPIELBERG, WITH ITS FORTRESS, AND THE PETERSBERG, WITH ITS GOTHIC DOME. IT IS NOW A TOWN OF MORE THAN 300,000 INHABITANTS, FOR THE MOST PART CZECHS AND KNOWN BY THE CZECH NAME BRNO.



MONASTERY AND CHURCH OF THE ORDER OF THE AUGUSTINS  
HANS MENDEL ENTERED THIS MONASTERY IN 1843 AND RECEIVED THE MONASTIC NAME OF GREGOR.  
THE OLD CONVENT CHURCH IS FOURTEENTH CENTURY GOTHIC OF DARK RED BRICK.

are produced by the hybrid, the law of segregation and the law of independent assortment can be easily explained.

Just as the chemist thinks of the most complicated compound as being built from a relatively small number of invariable atoms, so Mendel regarded the species as a mosaic of genes, the atoms of living organisms. It was no more nor less than an atomistic theory of the organic world which was developed before the astonished audience. The minutes of the meeting inform us that there were neither questions nor discussions. The audience dispersed and ceased to think about the matter—Mendel was disappointed but not discouraged. In all his modesty he knew that by his discoveries a new way into the unknown realm of science had been opened. "My time will come," he said to his friend Niessl.

Mendel's paper was published in the proceedings of the society for 1866. Mendel sent the separate prints to Carl

Naegeli in Munich, one of the outstanding biologists of those days, who occupied himself with experiments on plant hybridization. A correspondence developed and letters and views were exchanged between the two men. But even Naegeli didn't appreciate the importance of Mendel's discovery. In not one of his books or papers dealing with heredity did he even mention Mendel's name. So, the man and the work were forgotten.

When Mendel died in 1884, hundreds of mourners, his pupils, who remembered their beloved teacher, and the poor, to whom he had been always kind, attended the funeral. But although hundreds realized that they had lost a good friend, and other hundreds attended the funeral of a high dignitary, not a single one of those present recognized that a great scientist and investigator had passed away.

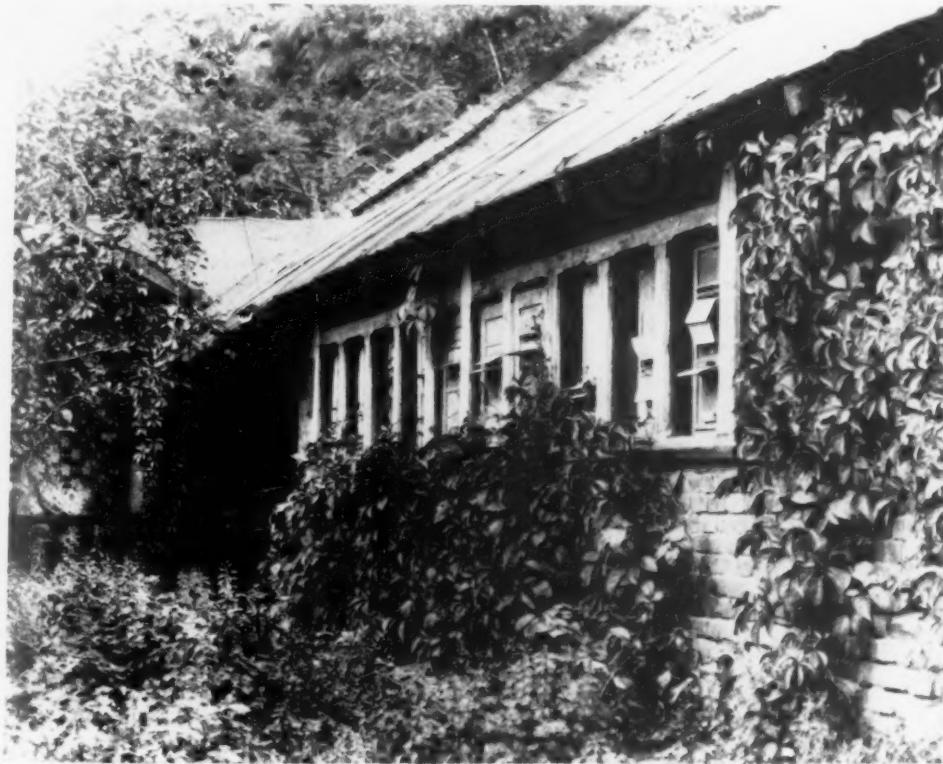
The story of the rediscovery and the sudden resurrection of Mendel's work is

a thrilling one. By a peculiar, but by no means an accidental, coincidence three investigators in three different places in Europe, DeVries in Amsterdam, Correns in Germany, Tschermak in Vienna, came almost at the same time across Mendel's paper and recognized at once its great importance.

Now the time had arrived for understanding, now "his time had come" and to an extent far beyond anything of which Mendel had dreamed. The little essay, published in the great volume of the Bruenn Society, has given stimulus to all branches of biology. The progress of research since the beginning of the century has built for Mendel a monument more durable and more imposing than any monument of marble, because not only has "Mendelism" become the

name of a whole vast province of investigation, but all living creatures which follow "Mendelian" laws in the hereditary transmission of their characters are said to "Mendelize."

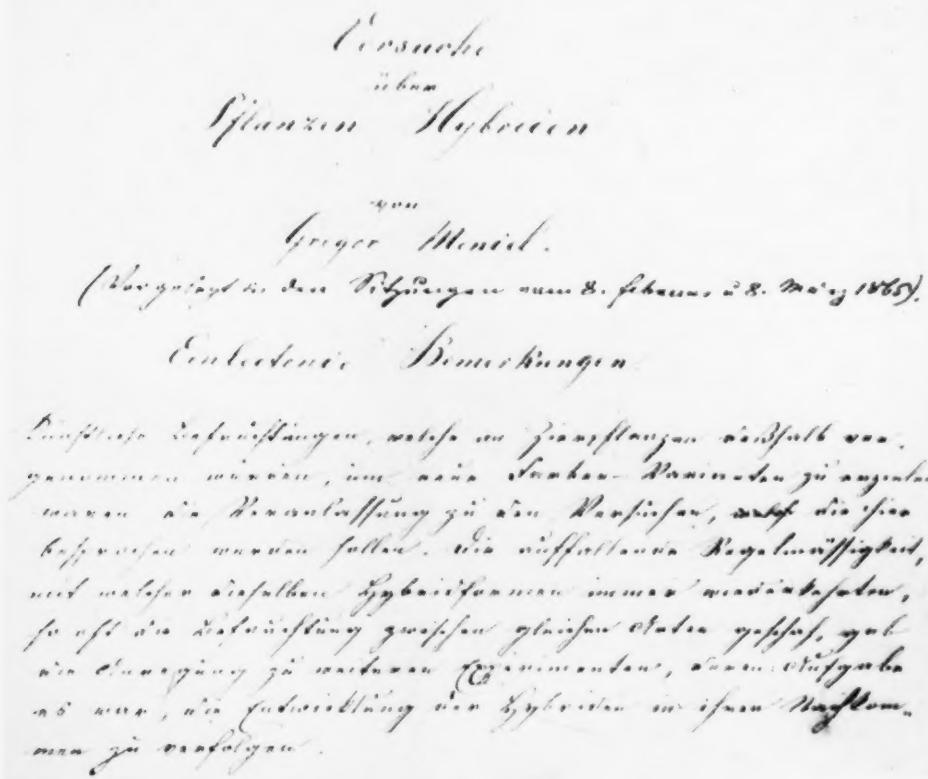
As illustrations, I will explain the practical consequences of Mendelian research by two examples only. The Swede, Nilsson-Ehle, was one of the first investigators who tried to use Mendelian methods to improve agricultural plants. In the cold climate of Sweden some wheat varieties, like the English square-hood wheat, were yielding well but were frozen easily. Other varieties, like the Swedish country wheat, were winter-hard but brought only a poor harvest. Nilsson-Ehle knew that in accordance with the Mendelian law of independent assortment, the breeder is able



MENDEL'S BEEHOUSE IN THE GARDEN OF THE MONASTERY  
AT TIMES, THIS APIARY HELD MORE THAN FIFTY SWARMS OF BEES.

to combine the desired characters of two different parents, like the chemist who combines the atoms to form various molecules or compounds. He crossed the late-ripening, well-yielding, square-hood wheat with the early-ripening, winter-hard, but poor-yielding Swedish country wheat. The resulting F<sub>1</sub> generation, however, was very discouraging. It was

pendent assortment of all characters will appear only in the F<sub>2</sub> generation. Self-fertilizing the F<sub>1</sub> plants he obtained an F<sub>2</sub> generation showing the ratio of nine late-ripe poor-yielding to three late-ripe well-yielding, to three early-ripe poor-yielding, to one early-ripe, well-yielding wheat plants. The desired combination of the two recessive characters, early-



PART OF THE FIRST PAGE OF MENDEL'S FAMOUS PAPER

uniform, in accordance with Mendel's first law, all individuals being late-ripe and poor-yielding, thus combining the two undesirable dominant characters. In pre-Mendelian times the breeder would have been discouraged and probably would have discontinued his efforts. Not so Nilsson-Ehle, who knew that the F<sub>1</sub> generation is hybrid, showing only the dominant traits, and that the inde-

ripen, well-yielding, appeared only in the smallest ratio, one in sixteen—but because recessives are always true-breeding, or as it is called "homozygote," Nilsson-Ehle had only to isolate these plants and to destroy all others in order to obtain a new true breeding early-ripe and well-yielding variety which after a few years gave a crop large enough to be sold. Thus, by the work of the Mendel-

ist, Nilsson-Ehle, culture of wheat was made possible even in the northern parts of Sweden and large amounts heretofore spent for imported wheat could be saved.

Another instance shows the importance of Mendelism for the understanding of human inheritance. Very soon after the rediscovery of Mendel's paper it became evident that the laws found by Mendel with his peas are valid also for animals and for human beings. Of course, the study of the laws of human heredity is limited and rendered more difficult by several obstacles. We can't make experiments with human beings. The laws of Mendel are statistical laws based upon large numbers of offspring, while the number of children in human families is generally small. But in spite of these difficulties it was found very soon that human characters are inherited in the same manner as the characters of the pea. We know, for instance, that the dark color of the iris of the eye is dominant, the light blue color recessive. I remember a tragicomical accident connected with this fact. At one of my lecture tours in a small town in Czechoslovakia, I spoke about the heredity of eye color in men and concluded that, while two dark-eyed parents may be hybrids in regard to eye color and thus may have children both with dark and blue eyes, the character blue-eyed, being recessive, is always pure. Hence two blue-eyed parents will have only blue-eyed children. A few months later I learned that a divorce had taken place in that small town. I was surprised and resolved to be very careful even with scientifically proved statements in the future.

Even more important is the Mendelian analysis of hereditary diseases. If we learn that the predisposition to a certain disease is inherited through a dominant gene, as diabetes, for instance, then we know that all persons carrying the gene will be sick. In this case all carriers can be easily recognized. In the case of re-



MENDEL MUSEUM  
IN THE AUGUSTIN MONASTERY HE ATTENDED.

cessive diseases, feeble-mindedness, for instance, we know that the recessive gene may be covered by the dominant gene



MENDEL MEMORIAL IN BRÜNN  
ERECTED BY "FRIENDS OF SCIENCE" IN 1910.

for health and that the person, seemingly healthy, may carry the disease and transmit it to his children.

With every year the influence of Mendel's modest work became more widespread. The theoretical explanation given by Mendel was based upon the hypothesis of a mechanism for the distribution and combination of the genes. To-day we know that exactly such a mechanism, as was seen by the prophetic eye of Mendel, exists in the chromosome

fruit-fly, *Drosophila*, was found to be the best object for genetical research. The parallelism between the behavior of the chromosomes and the mechanism of Mendelian inheritance was studied by hundreds of scientists, who were trying to determine even the location of the different genes within the different chromosomes and who started to devise so-called chromosome maps.

Correns, Baur and Goldschmidt in Germany; Bateson and his school in En-



THE FAMOUS EXPERIMENTAL GARDEN

IN THIS SMALL PLOT, ONLY ABOUT ONE HUNDRED-AND-TWENTY FEET LONG AND TWENTY FEET WIDE, MENDEL CONDUCTED HIS EXPERIMENTS ON PLANT GENETICS, USUALLY WORKING WITH PEA PLANTS.

apparatus of the nucleus of the cells. The development of research on chromosomes, from the observations of the chromosomes and their distribution by mitosis to the discovery of the reduction of the number of chromosomes in building the sex cells and finally to the audacious attempt to locate the single genes within the chromosomes, is all a story, exciting as a novel and at the same time one of the most grandiose chapters in the history of science. A tiny animal, the

gland; DeVries in Holland; Nilsson-Ehle in Sweden, are the outstanding geneticists of the first decade after 1900. But soon the picture changed. The Carnegie Institution for Genetic Research in Long Island, under the leadership of Davenport and later under Blakeslee, became one of the world's centers of genetic research. In 1910, T. H. Morgan, then at Columbia University, later at the California Institute of Technology, started his investigations with the fruit-fly, *Drosophila*,

sophila, and founded the largest and most active school of geneticists. The U. S. Department of Agriculture with its network of experimental stations connected with more than a hundred agricultural colleges became the most admirable organization for breeding of better crops and farm animals based upon the principles of Mendelism. The ideas developed by Mendel have found a new home here in the new world.

From 1905 to 1910, I tried by lectures and by articles to renew the memory of Mendel in my home country and to

explain the importance of Mendelism to the people. This was not always an easy task. Once I happened to be standing beside two old citizens of Bruenn, who were chatting before a picture of Mendel in a book-seller's window. "Who is that chap, Mendel, they are always talking about now?" asked one of them. "Don't you know?" replied the second. "It's the fellow who left the town of Bruenn an inheritance!" In the brain of the worthy man the term "heredity" had no meaning, but he understood well enough the sense of an inheritance or bequest.

#### SCIENCE AND WAR

IT is usually assumed that modern science, which produced long-range artillery and the bursting bomb, flame-throwers and poison gas, tanks and, above all, the airplane, has made war more horrible than it was in the past. In a sense it has. There is no doubt that the impact of mechanized warfare on the individual soldier's psychology is far more terrifying and requires greater moral and physical stamina to withstand than ever before. And the airplane, which has wiped out distances, has carried the war right to the home front, and slaughters not only soldiers but also women, and children, and the aged.

And yet, in the words of Major General Vandegrift, who speaks from his experience as commander of our Marines on Guadalcanal, modern science has also made war more humane. For the quick death suffered by those killed in battle or in air raids is not the worst of war's horrors. Far more terrible even than death in the wars of the past was the agony of the wounded left to die, and the usual accompaniment of war—famine and disease, which struck behind the

fronts as well with even greater force than the airplane to-day. So completely were they linked with war in popular consciousness, and so helpless did the world feel about them, that they are among the Four Horsemen of the Apocalypse. And not till modern science began to demonstrate that they were not inevitable was there an outcry against them—during the Crimean War, which produced Florence Nightingale.

To-day two of the sinister horsemen have been well-nigh eliminated. According to the latest figures, only 1 per cent. of those wounded on Guadalcanal have died, and even in Russia the death rate among the wounded is said to be only 1.5 per cent. And except for the deliberate starvation and its consequences imposed on Europe by the Nazis, famine has been beaten in the civilized parts of the world. The reasons for the first miracle are quick transportation and hospitalization of the wounded, and modern medical treatment with blood plasma and the sulfa drugs, which prevent infections and promote quick healing.—From an editorial in *The New York Times*.

# THE ORIGIN OF SUPERIOR MEN<sup>1</sup>

By DR. E. L. THORNDIKE

EMERITUS PROFESSOR OF EDUCATIONAL PSYCHOLOGY, TEACHERS COLLEGE, COLUMBIA UNIVERSITY

THE forty-eight states show noteworthy differences in the frequency of births of superior men. The number of persons recorded in "Who's Who in America" (1938-1939) per ten thousand of the population in 1880 is as shown in Column 1 of Table I. Massachusetts and Connecticut have over five times as many as Louisiana, Mississippi or New Mexico. If the number of women aged 20-44 in 1880 is used as a base, the differences are greater. If the white population of 1880 is used as a base, the differences, though reduced, remain substantial as shown in Column 4 of Table I. Massachusetts, Connecticut and the Northwestern States still show rates two or three times as high as those for some of the Southern States. If the populations at 1870 and 1880 and 1890, or any reasonably weighted average of the populations at 1860, 1870, 1880, 1890, and 1900 is used as a base, wide differences remain.

The persons listed in Cattell's "American Men of Science" (1938) represent a narrower field of superiority with a wider selection within that field. The births per ten thousand of the 1890 population are shown in Column 2 of Table I. The differences among states are of about the same magnitude as in the case of Who's Who men, and the rank order of the states is much like that in the case of Who's Who men. The use of the 1880 population, or the 1900 population, or any reasonably weighted average of the population from 1860 to 1910 would leave the general fact of great variation unaltered. Using the white population of 1890 as the base, we have the facts in Column 5 of Table I.

<sup>1</sup> This study was made possible by financial assistance from the Carnegie Corporation.

The persons who are listed in Cattell's "Leaders in Education" (1932), but are not listed in "Who's Who" for 1938-1939 (including its references to former entries) or in "American Men of Science" (1938), form a group of men and women much above the average in intelligence, achievement, and public and private virtues, though not on the average so able as the group in "Who's Who." The numbers for each state per hundred thousand of the state's 1880 population, total and white, are shown in Columns 3 and 6 of Table I.<sup>2</sup>

<sup>2</sup> Inclusion in "Who's Who" is evidence of ability and, though perhaps to a less degree, of service to the nation and world. But the data, as between states, are not strictly comparable. Of a dozen persons of equal achievement, those living in "superior" states are less likely to be included, because what may be called the *ex officio* entries in "Who's Who" (congressmen, professors in state universities and the like) are to some extent selected by geography as well as by merit. The influence of this defect is reduced in our results because only about a third of the famous persons of a state were born in it. But it is not reduced very much, since many more of them were born in that state than in an equally populated fraction of the other forty-seven states. It is also probable that ability in law, engineering, medicine, manufacturing and business is underweighted in comparison with ability in teaching, the ministry, government and public administration. Better evidence in some respects concerning the migration of the able and good is furnished by the facts for men of science presented in Cattell's "American Men of Science." The selection here is objective and impartial, it reaches down to younger ages, and less exalted levels of ability. Reputable men of science are far above the average in intellect, and somewhat above it in esthetic abilities. They rank high in both private and public morality. In business enterprise, worldly wisdom and energy they rank probably above the average teacher and clergyman, but below engineers and lawyers. By any reasonable criterion they would be placed in the top tenth of the population.

The facts of Table I are presented as samples of superior birth rates, not as authoritative measures. They favor states which had specially small populations in 1880 (or 1890 in the case of the "American Men of Science").<sup>3</sup>

The ratios of names appearing in the directories used to populations at any one time (which we shall call superior-birth rates) will be more or less unjust to individual states, favoring in general those which had smaller populations relatively at the time used by us than over the whole period during which the persons enrolled were born. Their birth-years are approximately as shown in Table II.

A better single measure for persons in "Who's Who" and for persons in "Leaders in Education" not in "Who's

TABLE I

## SAMPLE BIRTH-RATES OF SUPERIOR MEN AND WOMEN FOR EACH STATE

Column 1: Number in "Who's Who" per 10,000 population in 1880; Column 2: Number in "American Men of Science" per 10,000 population in 1890; Column 3: Number in "Leaders in Education" per 100,000 population in 1880, excluding any in "Who's Who" or "American Men of Science"; Column 4: Number in "Who's Who" per 10,000 white population in 1890; Column 5: Number in "American Men of Science" per 10,000 white population in 1890; Column 6: Number in "Leaders in Education" per 100,000 white population in 1880 excluding any in "Who's Who" or "American Men of Science."

<sup>3</sup> What we should like to have as authoritative measures in place of the facts of Table I for any state is the percentage of those born in it in any period, say 1880, or 1880-1889, or 1870-1909, who would, before they died, or before they reached some specified age, be enrolled in Who's Who, American Men of Science, or any other list significant of superiority. But to obtain such facts for all years and states is impossible; and even to obtain them only for those states for which the number of births is known for those periods to which accessions to Who's Who and the American Men of Science can be assigned, for those persons who have reached age fifty, would require an enormous amount of labor.

	1	2	3	4	5	6
Alabama .....	3.1	1.0	5.0	5.9	1.9	9.5
Arizona .....	4.0	2.3	7.4	4.6	3.6	8.6
Arkansas .....	2.4	1.1	5.2	3.2	1.6	7.1
California .....	6.4	4.6	6.2	7.2	5.0	7.0
Colorado .....	7.7	7.8	9.3	7.9	8.0	9.4
Connecticut .....	10.4	6.2	11.1	10.6	6.3	11.3
Delaware .....	7.4	2.9	8.2	9.1	3.5	10.0
Florida .....	3.2	1.2	3.3	6.1	2.0	6.3
Georgia .....	2.9	1.0	4.0	5.4	1.8	7.5
Idaho .....	12.9	7.1	12.3	14.5	7.7	13.8
Illinois .....	6.1	4.6	10.7	6.2	4.7	10.9
Indiana .....	5.2	5.2	13.5	5.3	5.3	13.8
Iowa .....	6.6	5.8	12.1	6.6	5.8	12.2
Kansas .....	5.1	4.9	15.2	5.3	5.0	15.9
Kentucky .....	3.5	1.7	5.7	4.1	2.0	6.8
Louisiana .....	2.1	1.1	3.2	4.4	2.2	6.6
Maine .....	7.0	5.3	17.0	7.0	5.3	17.0
Maryland .....	5.7	4.8	8.7	7.3	6.1	11.2
Massachusetts .....	11.2	6.8	13.0	11.4	6.8	13.2
Michigan .....	5.5	4.3	11.7	5.6	4.3	11.8
Minnesota .....	6.4	4.9	13.7	6.5	5.0	13.8
Mississippi .....	2.5	1.2	3.8	5.9	2.8	9.0
Missouri .....	4.8	3.2	10.1	5.1	3.3	10.8
Montana .....	10.2	6.7	15.3	11.4	7.5	17.1
Nebraska .....	6.6	4.1	19.7	6.6	4.1	19.8
Nevada .....	5.3	3.2	3.2	6.1	3.8	3.7
New Hampshire .....	7.6	5.6	13.3	7.6	5.6	13.3
New Jersey .....	6.1	3.1	5.0	6.3	3.2	5.1
New Mexico .....	2.0	1.9	2.5	2.2	2.1	2.8
New York .....	6.8	4.4	7.3	6.9	4.4	7.4
No. Carolina .....	3.7	1.7	5.4	5.9	2.5	8.7
No. Dakota .....	11.7	5.0	46.1	11.9	5.2	47.2
Ohio .....	6.5	4.8	12.5	6.7	5.0	12.8
Oklahoma .....	?	?	?	?	?	?
Oregon .....	6.7	5.0	10.3	7.2	5.3	11.0
Pennsylvania .....	5.3	3.6	8.6	5.4	3.7	8.8
Rhode Island .....	8.4	4.7	12.7	8.6	4.8	13.0
So. Carolina .....	3.5	1.8	5.9	8.8	4.4	15.1
So. Dakota .....	9.6	5.5	26.5	9.7	5.9	26.2
Tennessee .....	3.6	1.4	4.9	4.9	1.8	6.6
Texas .....	2.9	1.9	6.7	3.9	2.5	8.9
Utah .....	9.5	11.4	17.4	9.6	11.7	17.6
Vermont .....	7.6	5.9	12.9	7.7	5.9	13.0
Virginia .....	4.9	2.7	6.5	8.4	4.3	11.2
Washington .....	11.5	5.7	17.3	12.8	6.0	19.4
W. Virginia .....	4.2	2.5	9.4	4.4	2.6	9.8
Wisconsin .....	6.2	5.1	11.3	6.3	5.1	11.3
Wyoming .....	11.5	5.9	24.1	12.6	6.3	26.3

"Who's Who" or "American Men of Science" is obtained by dividing by the sum of the populations for 1870, 1880 and 1890. Four-fifths of the persons in "Who's Who" (38-39 edition) were born between 1865 and 1894, as were those in "Leaders in Education." Nearly three-fifths of those listed in "American Men of Science" were born between 1885 and

1905, so that division by the sum of the 1890 and 1900 populations may give juster measures for the "American Men of Science" than division by the 1890 population alone.

TABLE II  
AGE DISTRIBUTION OF SUPERIOR MEN

Year	Number born among a random thousand in		
	Who's Who, 1938-9	Leaders in Education	
		American Men of Science, 1938	but not in Who's Who or A.M.S.
Before 1860	49	3	34
1860-1864	59	22	41
1865-1869	120	28	60
1870-1874	167	75	89
1875-1879	178	55	134
1880-1884	145	92	148
1885-1889	124	113	188
1890-1894	87	148	183
1895-1899	56	153	91
1900-1904	12	166	30
1905-1909	3	124	1
1910 or later		21	1

The facts for each state by these measures appear in Table III. They still are imperfect as measures of the comparative productivity of superior persons in the forty-eight states, but the errors will be small in comparison with the differences shown, and the effect of the errors upon the correlations we shall later present will be mainly to act as a factor of safety, reducing them all slightly.

TABLE III

## SUPERIOR BIRTH RATES AND RANKS FOR EACH STATE

Column 1: Number in "Who's Who" (1938) per million in the sum of the 1870, 1880 and 1890 populations; Column 2: Number in "American Men of Science" (1938) per million in the sum of the 1890 and 1900 populations; Column 3: Number in "Leaders in Education" (1932) (but not in "Who's Who" or "American Men of Science") per million in the sum of 1870, 1880 and 1890 populations.

	1	Rank*	2	Rank*	3	Rank*
Ala.	103	41	47	47	17	39, 40
Ariz.	116	40	95	36	22	34
Ark.	79	46	52	44	17	39, 40
Calif.	211	16	206	22	20	36
Colo.	232	11	340	2	28	28, 29
Conn.	339	2	278	5	36	17, 18
Del.	248	9	139	31	27	30
Fla.	102	42	49	45, 46	11	46, 47
Ga.	97	44	44	48	13	43-45
Idaho	309	3	252	10	29	25-27
Ill.	200	20	203	24	35	19
Ind.	177	30	242	12	46	8
Iowa	226	12	267	7	42	11-15
Kan.	182	29	240	13	54	5-7
Ky.	118	39	79	40	19	37
La.	71	47	49	45, 46	11	46, 47
Maine	234	10	256	8, 9	57	2-4
Md.	193	24	226	18	29	25-27
Mass.	366	1	301	3	42	11-15
Mich.	183	27, 28	198	25	39	16
Minn.	199	21	210	21	42	11-15
Miss.	86	45	53	43	13	43-45
Mo.	157	33	146	30	33	20
Mont.	197	22, 23	249	11	30	24
Nebr.	183	27, 28	204	23	54	5-7
Nev.	217	15	167	28	13	43-45
N. H.	253	8	269	6	44	9
N. J.	197	22, 23	135	32	16	41, 42
N. M.	65	48	84	37	8	48
N. Y.	224	13	197	26	24	31
N. C.	126	35	76	41	18	38
N. D.	187	26	186	27	74	1
Ohio	219	14	227	16, 17	42	11-15
Okla.	120**	38	107	35	31**	22, 23
Ore.	201	19	218	19	31	22, 23
Pa.	173	31	163	29	28	28, 29
R. I.	278	5	211	20	42	11-15
S. C.	121	37	82	38	21	35
S. D.	205	17	256	8, 9	57	2-4
Tenn.	121	36	63	42	16	41, 42
Texas	101	43	81	39	23	32, 33
Utah	308	4	492	1	57	2-4
Vt.	255	7	288	4	43	10
Va.	169	32	125	33	23	32, 33
Wash.	189	25	233	15	29	25-27
W. Va.	144	34	111	34	32	21
Wis.	202	18	227	16, 17	36	17, 18
Wyo.	261	6	239	14	54	5-7

\* If two states have the same birth-rate of superior men, the ranks of both are given for each. For example, Michigan and Nebraska, with a rate of 183 for "Who's Who" persons are ranked 27, 28. Similarly, if three or more states have the same rank.

\*\* Estimated.

As a second, and in some respects better, method of computing state birth-rates of Who's Who persons, I have computed the facts of Table IVA, in which the number of persons reported in two thousand pages of "Who's Who" for 1838-1839 and born in 1856 through 1864 is divided by the total number of births in the state in question in 1860, and similarly for "Who's Who" persons born in 1866 through 1872 and the total births in 1870, "Who's Who" persons born in 1876 through 1884 and the total births in 1880, etc.

TABLE IVA

THE BIRTHS OF "WHO'S WHO" PERSONS IN EACH STATE (EDITION OF 1838) DURING CERTAIN PERIODS IN RELATION TO THE TOTAL NUMBER OF BIRTHS IN THE STATE AT APPROXIMATELY THE SAME PERIOD

	W(56-65) B 1860	W(66-75) B 1870	W(76-85) B 1880	W(86-95) B 1890	Rank
Maine .....	411	797	670	451	13
N. Hampshire ..	538	1289	738	361	7
Vermont .....	587	898	680	276	11
Massachusetts ..	653	1437	1041	513	2
Rhode Island ..	524	894	809	517	8
Connecticut .....	754	1150	998	504	4
New York .....	308	683	576	359	19
New Jersey .....	300	623	434	275	27, 28
Pennsylvania ..	254	520	394	228	32
Ohio .....	306	644	513	318	23
Indiana .....	231	417	399	278	33
Illinois .....	278	552	454	246	30
Michigan .....	251	668	458	266	27, 28
Wisconsin .....	377	532	425	259	29
Minnesota .....	442	682	473	257	20
Iowa .....	270	618	586	310	22
Missouri .....	174	402	324	246	34
No. Dakota .....	0	613	576	282	24, 25
So. Dakota .....	0	1538	901	335	5
Nebraska .....	497	891	425	291	16
Kansas .....	333	696	325	341	24, 25
Delaware .....	271	929	570	262	17
Maryland .....	264	516	452	271	31
Virginia .....	167	486	332	218	35
W. Virginia .....	170	411	285	159	36
No. Carolina .....	101	377	233	192	37

So. Carolina .....	136	372	208	154	38
Georgia .....	99	271	167	126	44
Florida .....	119	223	213	190	41
Kentucky .....	137	312	240	133	39
Tennessee .....	91	337	207	166	40
Alabama .....	94	300	189	126	42
Mississippi .....	100	211	173	98	44
Arkansas .....	98	252	117	89	47
Louisiana .....	78	222	134	82	48
Oklahoma .....	?	?	?	?	26*
Texas .....	95	287	173	134	43
Montana .....	?	637	1131	365	12
Idaho .....	?	1810	968	524	3
Wyoming .....	?	641	1064	681	10
Colorado .....	0	1035	1282	367	6
New Mexico .....	0	114	50	134	45
Arizona .....	?	0	770	269	18
Utah .....	297	878	630	339	15
Nevada .....	2941	1411	578	401	1
Washington .....	302	1464	717	328	9
Oregon .....	248	722	516	383	21
California .....	403	852	644	418	14

\* Estimated.

$W(56-65) = 100,000 \times \text{the number of persons on 2000 pages of Who's Who born in the state in 1856 to 1865 inclusive.}$

$W(66-75) = 100,000 \times \text{the number of persons on 2000 pages of Who's Who born in the state in 1866 to 1875 inclusive.}$

$W(76-85) = 100,000 \times \text{the number of persons on 2000 pages of Who's Who born in the state in 1876 to 1885 inclusive.}$

$W(86-95) = 100,000 \times \text{the number of persons on 2000 pages of Who's Who born in the state in 1886 to 1895 inclusive.}$

B 60 = the number of births in the state in 1860

B 70 = the number of births in the state in 1870

B 80 = the number of births in the state in 1880

B 90 = the number of births in the state in 1890

Table IVB reports the same facts but expressed in each case as a deviation from the median of the column's measures. The measures for 56 to 65, 76 to 85, and 86 to 95 are multiplied by factors to give them general equality with the 66 to 75 measures and thus show more clearly the degree of consistency of the rates for the same state at different periods.

The correlation of the sum of the rates of Table IVA with the "Who's Who" rates in Table III is .88. The correlation for a weighted sum in which each period

is given approximately equal weight is .90.

I have used this method for the persons listed on a thousand pages of the 1938 edition of "American Men of Science."<sup>4</sup> The correlations corresponding to the .88 and .90 for "Who's Who" persons are .92 and .90. It seemed unnecessary to undertake these very laborious computations for the "Leaders in Education."

As a general measure of a State's relative productivity of superior persons we may use a composite (called SBQ) of the three per-populations measures of Table III and the two per-births measures. (I use the averages, but medians would do as well.) Any reasonable weighting of the five will do; I give approximately equal weight to each of the five, which means that "Who's Who" measures and "American Men of Science" measures each have about twice the weight of the "Leaders in Education" measures. The values of SBQ for each state appear in Table V. The numbers are reduced to values such that the median state is 100, but their relative proportions are approximately the same as would be found in the per population rates or in the per births rates. For example, the state with the highest SBQ (170) does produce at a rate about five times that of the state with the lowest SBQ (32). These composite rates or SBQ's for the production of superior persons are still not perfect, but would probably correlate well over .90 with the ratings that would be found if the achievements of every person born from 1855 to 1900 were examined and evaluated by a competent jury of experts and if those put in the top one or two per cent. were classified by state and year of birth and the resulting numbers were compared with the total numbers of births in each state in each year.

<sup>4</sup> Tables like IVA and IVB were prepared but are omitted here for lack of space.

TABLE IVB

THE FACTS OF TABLE IVA, EACH BEING DIVIDED BY 10, EXPRESSED AS A DEVIATION FROM THE MEDIAN OF ITS COLUMN, AND MULTIPLIED BY A FACTOR (1.65) FOR THE 1860 COLUMN, 1.00 FOR THE 1870 COLUMN, 1.26 FOR THE 1880 COLUMN, AND 3.0 FOR THE 1890 COLUMN) TO MAKE THE VARIABILITY EQUAL FOR EACH COLUMN, AND PERMIT EASY COMPARISONS OF THE BIRTH-RATES OF THE SAME STATE IN THE FOUR PERIODS

	$\frac{W(56-65)}{B\ 1860}$	$\frac{W(66-75)}{B\ 1870}$	$\frac{W(76-85)}{B\ 1880}$	$\frac{W(86-95)}{B\ 1890}$
Maine .....	23	16	26	54
New Hampshire .....	43	65	34	27
Vermont .....	53	26	28	0
Massachusetts .....	63	80	78	72
Rhode Island .....	58	26	43	72
Connecticut .....	79	52	67	69
New York .....	5	5	14	24
New Jersey .....	5	-1	-4	0
Pennsylvania .....	-3	-11	-9	-15
Ohio .....	5	1	6	12
Indiana .....	-7	-21	-9	0
Illinois .....	0	-8	-1	-9
Michigan .....	-3	3	-1	-3
Wisconsin .....	16	-10	-5	-6
Minnesota .....	28	5	1	6
Iowa .....	0	-2	15	12
Missouri .....	-16	-23	-18	-9
North Dakota .....	-8*	-2	14	3
South Dakota .....	-8*	90	55	18
Nebraska .....	36	26	-5	6
Kansas .....	10	6	-18	21
Delaware .....	0	29	14	-3
Maryland .....	-2	-12	-1	0
Virginia .....	-18	-15	-16	-18
West Virginia .....	-16	-22	-23	-36
North Carolina .....	-28	-26	-26	-24
South Carolina .....	-23	-26	-33	-36
Georgia .....	-30	-36	-38	-45
Florida .....	-26	-41	-32	-24
Kentucky .....	-23	-32	-28	-42
Tennessee .....	-30	-30	-33	-33
Alabama .....	-30	-33	-35	-45
Mississippi .....	-28	-42	-37	-54
Arkansas .....	-30	-38	-44	-57
Louisiana .....	-33	-41	-42	-57
Oklahoma .....	?	?	?	?
Texas .....	-30	-35	-36	-42
Montana .....	?	0	84	27

## THE ORIGIN OF SUPERIOR MEN

429

Idaho .....	?	118	63	75
Wyoming .....	?	1	75	123
Colorado .....	?	40	104	27
New Mexico .....	?	-52	-51	-42
Arizona .....	?	?	39	-3
Utah .....	3	24	21	18
Nevada .....	440	78	14	39
Washington .....	5	83	32	15
Oregon .....	-5	9	6	33
California .....	21	22	23	42

\* Estimated.

I have sought in vain for data on birthplace for any large groups of musicians, artists, highly-skilled craftsmen, engineers, clergymen or the like to extend Table III and Table V. I have also sought in vain for data on the birthplaces of criminals, feeble-minded, psychopaths and other defectives, delin-

TABLE V  
SUPERIOR BIRTH-RATE OR QUOTIENT, SBQ, AND  
RANK FOR EACH STATE

State	Rate SBQ	Rank	State	Rate SBQ	Rank
Ala. ....	41	42	Neb. ....	115	16
Ariz. ....	72	33	Nev. ....	113	18
Ark. ....	37	44	N. H. ....	140	6
Cal. ....	103	22	N. J. ....	77	32
Colo. ....	141	5	N. M. ....	35	47
Conn. ....	148	3	N. Y. ....	98	26
Del. ....	93	29	N. C. ....	51	38
Fla. ....	38	43	N. D. ....	118	12
Ga. ....	36	46	Ohio ....	110	19
Ida. ....	142	4	Oklahoma ....	71	34
Ill. ....	97	27	Ore. ....	102	24
Ind. ....	104	21	Pa. ....	83	30
Iowa ...	116	13	R. I. ....	128	11
Kan. ....	115	14	S. C. ....	51	37
Ky. ....	50	39	S. D. ....	139	7
La. ....	32	48	Tenn. ....	46	41
Me. ....	130	10	Tex. ....	49	40
Md. ....	95	28	Utah ...	170	1
Mass. ....	164	2	Vt. ....	132	9
Mich. ....	99	25	Va. ....	70	35
Minn. ....	108	20	Wash. ....	115	15
Miss. ....	36	45	W. Va. ....	67	36
Mo. ....	78	31	Wis. ....	102	23
Mont. ....	114	17	Wyo. ....	136	8

quents and dependents to make a table to contrast with Table III and Table V. It is probable, but not at all certain, that the states have differed in the production of superior artists, technicians, farmers, etc., in the same ways that they have differed in the production of superior workers in science and education. It is probable, indeed almost certain, that a state which produced relatively many high on a scale for human quality produced relatively few that were low in such a scale.

It is then worth while to examine the affiliations (*i.e.*, the correlations or covariances) of high per-capita production of the sort measured by SBQ. For the year 1930 or near it, I have, for each state, six instructive measures;

G, an index of the general goodness of life for good people, based on 37 measures.

I, an index of the per capita income of the residents, based on 9 measures.

P, an index of certain personal qualities of the residents, based on 10 measures.

G<sub>wh</sub>, an approximate index of the goodness of life for good white people, based on 9 measures.

I<sub>wh</sub>, an approximate index of the per capita income of white residents, based on 3 measures.

P<sub>wh</sub>, an approximate index of the personal qualities of white residents based on 5 measures.

The constituent measures and their weights are described in Note 2 at the end of this article.

We would prefer to study measures of the condition of each state in 1870, 1880, 1890, and 1900 rather than these measures of its condition in 1930, but only a very few are available for these earlier years. For 1900, I have measures of certain significant facts, namely the percentage of native whites aged ten or over that were illiterate, the percentage of farms that were owned by those living on them, the percentage of non-farm

homes owned by those living in them, and an index, G P of 1900, described in Note 3 at the end of this article.

The correlations, given in Table VI, show very close bonds between SBQ and the quality of the population in 1930. Whatever causes the former accounts for three fourths of the variation in the latter (.87<sup>2</sup>). No combination of the measures in a multiple correlation will add anything considerable to this. In particular, income adds almost nothing.

The combined force of  $P_{wh}$  and per cent. of colored reversed accounts for 68 per cent. of the variation in SBQ, the allotment of the 68 per cent. being as follows:

- .27 per cent. is due to what is measured by  $P_{wh}$  and not by per cent. colored reversed.
- .13 per cent. is due to what is measured by per cent. colored reversed and not by  $P_{wh}$ .
- .28 per cent. is due to something that is common to  $P_{wh}$  and per cent. colored reversed.

The relation between the 1930 P and the births a half-century before is due in only small measure to the influence of the superior persons in question upon the residents of the state in which they were born. For only a small minority of them stay there. The medians are 34% for "Who's Who" persons and 19% for "American Men of Science." And those that emigrate do not go especially to states which are high in P in 1930. On the contrary they favor states low in P.<sup>5</sup> Doubtless superior men benefit the state where they live, but the important fact is that the kind of state which gives birth to many of them probably was high in P in 1880.

It certainly was in 1900. The correlation of the three birthrates with even so partial a symptom of P as native white literacy is .77. The correlation with the

<sup>5</sup> This will be substantiated in a later article on the interstate migration of superior men.

percentage of farmers owning their farms is .63. The correlation with ownership of non-farm homes is .37. There can be little doubt that if the ten items

TABLE VI  
CORRELATIONS OF A COMPOSITE SUPERIOR-BIRTH RATE, SBQ, FOR THE 48 STATES IN 1930

With G	of 1930 .....	.79
" P	" "	.87
" I	" "	.48
" G <sub>wh</sub>	" "	.72
" P <sub>wh</sub>	" "	.80
" I <sub>wh</sub>	" "	.06
With percentage of colored (reversed) in 1930 .....		.77
With G P of 1900 .....		.81
With native white literacy of 1900 .....		.77
With percentage of farmers owning their farms in 1900 .....		.63
With percentage of non-farm population owning their homes in 1900 .....		.37

of the P score were available for 1900, the correlation of SBQ with P of 1900 would be over .80. If these items were available for the white population of 1900 the correlation with a P for whites alone in 1900 would also almost certainly be over .70. I know of no facts which would cause the correlations to be lower in 1870 or 1880, and there are some facts which would cause them to be higher.

We may conclude therefore that the production of superior men is surely not an accident, that it has only a slight affiliation with income, that it is closely related to the kind of persons residing in New England and in the block formed by Colorado, Idaho, North Dakota, South Dakota, Utah and Wyoming, from 1870 to 1900, and that these persons probably diverged from the average of the country toward the qualities which make persons in 1930 learn to read, graduate from high school, spend public funds on libraries rather than roads and sewers, own their homes, avoid homicide, be free from syphilis, etc., as measured by the Index P.

## APPENDIX

## NOTE 1—COMPARABLE INVESTIGATIONS

Geisert has computed the ratio of the percentage of "Who's Who" persons born in Virginia in 1850-1860 to the percentage of white women 20 to 44 years of age in Virginia at that period, and similarly for each of the ten other states of the Southeast. (Geisert, H. L., "The Trend of the Interregional Migration of Talent: The Southeast, 1899-1936," 1939. *Social Forces*, 18: 41-47.) He has done this also for the period 1884 to 1886. (For this period, native-born white women were used.) The Southeastern states were in general below the ratio (1.00) for the United States as a whole. Their ratios as estimated from Geisert's chart were as shown below:

	1850-1860	1884-1886
Alabama .....	.52	.68
Arkansas .....	.25	.41
Florida .....	1.00	.76
Georgia .....	.59	.74
Kentucky .....	.62	.67
Louisiana .....	.58	.60
Mississippi .....	.58	.83
North Carolina .....	.52	.81
South Carolina .....	1.04	1.26
Tennessee .....	.44	.69
Virginia .....	.76	1.17

His figures for the '84-'86 group correlate .91½, and the averages of his figures for the two periods correlate .90½, with our figures for the number divided by the white population in 1880.

Vance has recently reported the "average birth rate" of native-born whites included in the "Dictionary of American Biography" and born from 1790 to 1860, reckoned on the native-born white population. (Vance, R. P., "The Geography of Distribution: The Nation and Its Regions 1790-1927," 1939. *Social Forces*, 18: 168-179.) The District of Columbia was highest with a rate of 31.4 per million. Massachusetts, Connecticut and Rhode Island had above 16.0. Maine, New Hampshire, Vermont, New York and South Carolina had from 12.0 to 15.9. New Jersey, Pennsylvania, Delaware, Maryland, Virginia, West Virginia and Georgia had from 8.0 to 11.9. Ohio, Michigan, Wisconsin, Kentucky, Tennessee, North Carolina, Alabama, Mississippi and Louisiana had from 4.0 to 7.9. The other states had less than 4.0. If native-born Negroes had been included these rates would, of course, have been very different, but the general magnitude of the variation would probably have been increased.

In those early years the ranking of the eastern states in the production of superior men was much like what it is now (the correlation for the 24 listed above being .73 or .76 between Vance and Thorndike ranks according as the Thorndike ranks are on a basis of total population or white population). The western states and territories were then all very low, and about equally low by Vance, but possibly the populations he used as bases for them were too large, or especially lacking in women.

## NOTE 2.—CONSTITUENTS OF THE G SCORE

Item*	ITEMS OF HEALTH	Approximate weight for states
131 Infant death-rate reversed .....	13	
132 General death-rate reversed .....	9	
134 Typhoid death-rate reversed .....	5½	
136 Appendicitis death-rate reversed .....	3½	
137 Puerperal diseases death-rate reversed .....	5½	
ITEMS OF EDUCATION		
53 Per capita public expenditures for schools .....	8	
54 Per capita public expenditures for teachers' salaries .....	7	
55 Per capita public expenditures for textbooks and supplies .....	8	
56 Per capita public expenditures for libraries and museums .....	6	
21 Percentage of persons sixteen to seventeen attending schools .....	4½	
22 Percentage of persons eighteen to twenty attending schools .....	7½	
23 Average salary, high-school teachers, elementary-school teachers, and supervisors .....	7½	
ITEMS OF RECREATION		
57 Per capita public expenditures for recreation .....	7½	
17 Per capita acreage of public parks .....	2	
ECONOMIC AND "SOCIAL" ITEMS		
107 Rarity of extreme poverty .....	6½	
108 Rarity of less extreme poverty .....	6½	
153 Infrequency of gainful employment for boys 10-14 .....	4½	

154 Infrequency of gainful employment for girls 10-14	5½
223 Average wage of workers in factories	4
106 Frequency of home ownership (per capita number of homes owned)	6
248 Per capita support of the Y. M. C. A.	6
201 Excess of physicians, nurses, and teachers over male domestic servants	6
98 Per capita domestic installations of electricity	5½
99 Per capita domestic installations of gas	7
102 Per capita number of automobiles	5
103 Per capita domestic installations of telephones	10
104 Per capita domestic installations of radios	6½

## OTHER ITEMS

31 Percentage of literacy in the total population	6
25 Per capita circulation of Better Homes and Gardens, Good Housekeeping and the National Geographic Magazine	5½
26 Per capita circulation of the Literary Digest	4
133 Death rate from syphilis (reversed)	3½
241 Death rate from homicide (reversed)	3½
243 Death rate from automobile accidents (reversed)	3½
12 Per capita value of asylums, schools, libraries, museums, and parks owned by the public	6
16 Ratio of value of schools, etc., to value of jails, etc.	3
11 Per capita public property minus public debt	5

\* The items are more fully described on pages 173 to 187 of "Your City" by E. L. Thorndike, and also in *Ann. N. Y. Acad. Sci.*, 39: 214-223.

After the 37 scores were multiplied by amounts such as to make their standard deviations be proportional to the numbers listed above as approximate weights, the sum for each state (called G3) was combined with a score (G1) which was computed by subtracting the number of features among the 37 in which that

state was below the median of the 48 states from the number in which it was above the median of the 48. G3 and G1 had relative weights of approximately 2 and 1 respectively in the final G score.

It should be kept in mind that Items 11, 12, 16, 56, and 57 are for a state's own property, debt, and expenditures, not for these plus those of the smaller governmental units within its boundaries.

## CONSTITUENTS OF THE I SCORE

	Approximate weight for states
Income tax returns (over \$2,500)	15
Income tax returns (over \$5,000)	7
Average wages: teachers and supervisors	3½
Average wages: retail store employees	7
Average wages: factory employees	7
Expenditures: rent (or equivalent)	3½
Expenditures: food-store sales	4½
Expenditures: cigar-store sales	1
Expenditures: drug-store sales	1

This list has one notable weakness, in that the expenditures are such as respectable people make for respectable purposes. The expenditures for prostitutes, gambling, forbidden drugs, intoxicants, and more or less disreputable entertainment in these cities could not be estimated. This weakness acts as a factor of safety in the case of some of our most important conclusions.

## CONSTITUENTS OF THE P SCORE

The personal qualities index, P, is a weighted composite of the deviations from the median in the items listed below, the weights being approximately as stated.

Item	Approximate weight for states
30 Per capita number of graduates from public high schools in 1934	5
261 Percentage which public expenditures for the maintenance of libraries was of the total	2
31 Percentage of illiteracy (reversed)	2½

33 Percentage of illiteracy among those aged 15-24 (reversed) .....	2 $\frac{1}{2}$
106 Per capita number of homes owned .....	5
201 Per capita number of physicians, nurses and teachers minus male domestic servants .....	4
103 Per capita number of telephones .....	2 $\frac{1}{2}$
207d Number of male dentists divided by number of male lawyers .....	2
133 Per capita number of deaths from syphilis (reversed) .....	2 $\frac{1}{2}$
241 Per capita number of deaths from homicide (reversed) .....	2 $\frac{1}{2}$

*Constituents of G<sub>wh</sub>:* Items 131, 134, 137, 21, 22, 153, 154, 104, and 243 from the G list above, but in each case for the white population of the state. The weights were approximately as in the G composite.

*Constituents of P<sub>wh</sub>:* Items 31, 106, 133 and 241 from the P list above, but computed for the white population, and also the percentage of white farmers owning their farms.

#### NOTE 3

- G P of 1900 is a composite score including:
- (1) the percentage of residents 5 to 18 years old enrolled in public schools.
  - (2) the number of days public schools were in session.
  - (3) the expenditures per pupil in actual attendance for teachers and supervisors.
  - (4) the expenditures per pupil in actual attendance for all other items, excluding outlays for buildings and interest on bonds.
  - (5) the percentage of literacy for the white population aged 10 or over.
  - (6) the percentage of farmers owning their farms.
  - (7) the percentage of non-farm families owning their homes.
  - (8) the percentage which the white population was of the total population.

## CRITERIA OF THE EMPIRICAL METHOD

By Dr. PAUL CRISSMAN

PROFESSOR OF PSYCHOLOGY, UNIVERSITY OF WYOMING

In its widest sense, the meaning of "empirical" propositions may best be understood when contrasted with that of "formal" ones. Formal propositions consist of the analytic statements established by logic and mathematics; empirical propositions (hypotheses) consist of the synthetic statements verified by reference to existential objects and events. Formal propositions derive their validity from conventions, and, from the point of view of empiricism, are materially empty and constitute a system of tautologies. Formal propositions concern themselves solely with the structure of verbal systems and the conventions whereby terms and propositions of one language may be translated into terms and propositions of another and different language, and are, in any empirical sense, wholly devoid of "truth" value. In other words, terms and propositions

refer to or designate (1) other terms and propositions, and (2) perceptual objects and events, or identities discernible in or among such objects and events. In sum, if a hypothesis be empirical, it must designate some property or invariant relation exemplified in some class or domain of things or events, or else imply other propositions that terminate in such reference.

Now empirical science, our scientists and scientific text-books tell us, is concerned with "facts." So it is, the tested hypotheses that constitute scientific knowledge are suggested by facts and are in turn verified by reference to them. But what are facts?

The word "fact" embraces at least three types of referents. (1) "Fact" sometimes denotes objects and events discriminable in sense perception, together with relations perceived between them.

"The end of this pointer coincides with that mark on the scale," "This band of color lies between those two bands," are facts in this sense. Facts in this sense are distinct from the hypotheses we make about them; indeed, such facts are instituted or sought out by us in order to test the hypotheses we formulate. (2) "Fact" sometimes denotes propositions or judgments which *interpret* the data discriminated in sense perception. "This object is ferrous," "That object is a protozoan," are facts in this sense. All inquiry must take for granted a host of facts of this kind, although we may later reject some of them as false. (3) "Fact" also denotes propositions which truly assert some "invariant relation" or "constant conjunction of characters" between or among a plurality of things and events. "All planets revolve about the sun at velocities such that their radii from the sun describe equal areas in equal times," "Any nerve fiber must either respond with its whole capacity for response or none at all," are facts in this sense. A hypothesis is made "true," is "verified" and thereby becomes a fact when, as an experimental operation, it leads to the institution or discovery of facts in the first sense.

Consequently, facts are not determinate entities existing in nature that command attention in virtue of characteristics intrinsic to them; they are not, like berries on a bush, just waiting there for any one to pluck who runs. Facts, in so far as they are significant for scientific inquiry, are instituted or sought out by us for the purpose of testing a hypothesis. They are relative to the purposes of the inquirer on the one hand, and to the body of antecedently verified knowledge relevant to the particular inquiry on the other hand. Scientific inquiry is purposive; it is no mere idle staring at some inchoate flux of sensory elements passing in review before awareness. Some hypothesis, however arrived

at, guides and directs all significant inquiry; otherwise we should never look for or seek to institute any facts. To paraphrase the famous dictum of Kant, hypotheses without perceptual facts are devoid of empirical meaning, perceptual facts uninformed by hypotheses are blind or unrecognized.

Thus both concepts (hypotheses) and percepts (existential data) are essential to empirical science. The relation between them is reciprocal; the hypothesis embodies that which is *known* of the percepts, the percept constitutes the objective or public data of which knowledge is had. Moreover, there is another sense in which the distinction between hypothesis and perceptual fact is relative, when by a hypothesis is meant a proposition which *may* be true, but for which the perceptual evidence in verification of it is never complete. Since it is impossible to demonstrate the non-existence of negative instances, we can never attain complete proof for any hypothesis the number of whose existential referents is indeterminate. Moreover, this denotative indeterminateness is characteristic of all scientific hypotheses. Hence the commonplace that scientific laws are at best only more or less probable. Suppose, e.g., we assert that the volume of a gas varies inversely as the pressure exerted upon it, or that two or more bodies revolving about the sun move at velocities such that their radii describe equal areas in equal times. Assume that, within certain limits, a gas under terrestrial conditions will always vary in volume approximately as described; assume that, within the limits of the conditions set by the solar system, planetary motions will always conform to Kepler's laws; yet, for aught we know, there *may* exist elsewhere in the universe domains wherein a gas will not behave as described and where Kepler's laws of planetary motion will not hold true.

In terms of the meaning of "empirical" distinguished above on the one hand, and of the interdependence between hypotheses and perceptual facts on the other, let us consider a supposed instance of verification of a hypothesis. Take, for example, the hypothesis that  $H_2O$ , under pressure of one atmosphere, will always boil at 100 degrees Centigrade. Suppose we satisfy the conditions required by the hypothesis and then find that in the experiment the  $H_2O$  is actually observed to boil at the temperature prescribed. This "crucial" experiment is then supposed to "verify" the hypothesis. Yet, even assuming no error in measurement, this experiment proves only that the particular  $H_2O$  employed in the experiment was observed to boil at the instant when the measuring rod was observed to register 100 degrees Centigrade. By what logic, then, do we infer therefrom that when the same conditions are fulfilled the same temporal coincidence between boiling and a certain temperature reading will always be observed? The answer is, by no valid logic, for if we make such an inference, we commit the obvious fallacy of reasoning from one to all. Indeed, it is highly doubtful that, on the basis of a single observation of the temporal conjunction of two such characters, it would ever occur to us that the two characters were related in any way other than by chance.

Suppose, however, we repeat the experiment a number of times and observe the same results each time. Does not this, then, prove the hypothesis? Unhappily, it does so no more than the single experiment. For the number of such possible experiments is indeterminate if not indeed infinite; one "crucial" experiment proves precisely as much or as little as does any number of repetitions of it. For, if we ascribe to all possible instances of a phenomenon some property or relation observed to hold only of a number of selected in-

stances of it, we commit the simple fallacy of reasoning from some to all. But to reason from some to all is neither more nor less fallacious than to reason from one to all; indeed, there are no degrees of fallaciousness. In truth, the ascription of necessity to the coincidence between boiling and a given temperature reading observed in a number of instances is but the verbalization of that inexpungable habit of mind whereby we come to expect the same results each time the experiment is repeated. Expectation, however, is a psychological attitude; it is not demonstration of proof, for this latter is a logical process. Expectations do of course come true, and, for practical purposes, the obtainment of the same results by repetitions of the same experiment does in fact sooner or later succeed in banishing doubt, but this again is a psychological, not a logical, process. It is in dissipation of doubt, whether by one or by many experiments, that verification at least in part consists.

But verification is more than the dispelment of doubt; it is, in its more positive phase, the establishment of well-grounded belief. However, all depends upon the manner in which belief is established. In the words of a recent writer,<sup>1</sup> the belief in the truth of a hypothesis is established "in a simultaneous experience of the concepts and the given. The process of verification consists in the observation of instances of the characters expressed in a proposition. One may say that propositions correspond to, or agree with, experience. This relation of a true proposition to experience is fundamental and can be explained only in terms of synonyms; the fundamental fact is that we can determine the correspondence to experience of propositions about experience." Thereby alone is belief established or a hypothesis verified. But this again is a psychological, not a logical, process.

<sup>1</sup> V. F. Lenzen, "Physical Theory," p. 272.

Moreover, it is commonly supposed by scientists that a single crucial experiment may often decide between two rival theories.<sup>2</sup> For if one theory implies a verifiable proposition which contradicts a proposition implied by a second theory, by performing the experiment, it is believed, we can then eliminate one of them.

Consider two hypotheses:  $H_1$ , the hypothesis that light consists of very small particles traveling at great speeds, and  $H_2$ , the hypothesis that light is a form of wave motion. Both hypotheses explain a class of events  $E$ , e.g., the rectilinear propagation of light, the refraction of light, the reflection of light. But  $H_1$  implies the proposition  $p_1$  that the velocity of light in water is *greater* than in air; while  $H_2$  implies the proposition  $p_2$  that the velocity of light in water is *less* than in air. Now  $p_1$  and  $p_2$  can not both be true. Here, it would seem, is an ideal case for performing a *crucial* experiment. If  $p_2$  should be confirmed by experiment,  $p_1$  would be refuted, and we could validly conclude that the hypothesis  $p_1$  is false. Yet nearly a century ago Foucault showed that light travels faster in air than in water. Accordingly, the corpuscular theory of light should have been discarded once and for all.

Yet recent physics has revived Newton's corpuscular hypothesis in order to account for certain optical effects. Must we not then qualify this doctrine of crucial experiments?

The answer is simple, but calls attention once more to the interdependence between theory and observation. In order to deduce the proposition  $p_1$  from  $H_1$ , and in order to perform the experiment of Foucault, many other assumptions,

<sup>2</sup> This point, as well as the two illustrations cited in implementation of it, we borrow from Cohen and Nagel's "An Introduction to Logic and Scientific Method," pp. 219-221. Moreover, much of the language of this section of our paper, as well as a number of illustrations appearing elsewhere in it, are from the same source.

$K$ , must be made about the nature of light and the instruments we employ in measuring its velocity. As a result, it is not only the hypothesis  $H_1$  that is tested by the experiment, it is  $H_1$  and  $K$ . The logic of the crucial experiment therefore is as follows: If  $H_1$  and  $K$ , then  $p_1$ ; but  $p_1$  is false; therefore either  $H_1$  is false or  $K$  (in part or in whole) is false. Now if we have adequate grounds for believing that  $K$  is not false,  $H_1$  is refuted by the experiment. Nevertheless, the experiment tests *both*  $H_1$  and  $K$ . If, in the interest of consistency, it is found necessary to revise some one or another of the assumptions contained in  $K$ , the crucial experiment must be reinterpreted, and it need not then decide against  $H_1$ .

Every experiment, therefore, tests not *only* an isolated hypothesis, but *also* the whole body of relevant knowledge logically involved in it. If the experiment is claimed to refute an isolated hypothesis, this is because the other assumptions relevant to it are believed to be well founded. But this latter belief may later turn out to be questionable or even mistaken.

This point is important enough to deserve reinforcement by another illustration. Suppose we wish to discover whether physical space is Euclidean, i.e., whether the sum of the angles of a physical triangle is equal to two right angles. We select as vertices of such a triangle three stars, and as its sides the paths of light rays traveling from vertex to vertex. By making a series of measurements we can obtain the magnitude of each of the angles of this triangle. Suppose the sum of their several magnitudes is *less* than two right angles. Must we then conclude that Euclidean geometry is not truly descriptive of physical space? Not at all. At least three alternative explanations are open to us: (a) we may account for the difference between the theoretical and observed values in terms

of errors in measurement; (b) we may conclude that physical space is non-Euclidean; or, (c) we may conclude that the lines joining the vertices of the triangle are not straight lines, *i.e.*, we may conclude that Euclidean geometry is physically true, but that light does not travel in Euclidean straight lines in interstellar space. If we accept the first alternative then, as descriptive of physical space, Euclidean geometry may be either true or false; if we accept the second alternative, we do so on the assumption that light travels rectilinearly, an assumption which, although supported by much evidence, is not indubitable; if we accept the third alternative, it may be because we have evidence for denying the rectilinear propagation of light, or else because greater consistency is maintained in the body of our physical knowledge as a consequence of this denial.

"Crucial experiments," we again conclude, are crucial against a hypothesis only in case we possess a set of assumptions which we are unwilling to surrender. But no guarantee can be given that some portion of such assumptions will not later be abandoned.

In order that a hypothesis qualify as empirically true or verified, it must satisfy the following criteria: (1) it must be *testable*; (2) it must be *consistent*; and, (3) it should be as *simple* as possible.

(1) The hypothesis must be testable: *i.e.*, it must prescribe some definite mode of operation, either of observation or of experiment, whereby its "truth" value can be tested. In operational terms, the hypothesis must be statable in such form as to prescribe specific operations which institute the phenomena (facts in the first sense) requisite to satisfy it. Because it can not be translated into a definite experimental operation, the hypothesis that "God is the First Cause of all events in nature" is untestable and hence is empirically meaningless. In contrast,

Kepler's laws of planetary motion *are* verifiable, because they lead to the discovery of events that satisfy them.

Put otherwise, a hypothesis must be formulated in such a manner that deductions can be made from it, and that a decision can be reached as to whether or no it explains the facts considered. This decision may be reached either directly or indirectly. It is reached *directly* when the hypothesis is testable without the mediation of other hypotheses deducible from or related to it, or when the hypothesis itself prescribes operations that institute the data that satisfy it. The hypothesis that " $\text{H}_2\text{O}$ , under pressure of one atmosphere, will boil at 100 degrees Centigrade," or that, "Within certain limits, and under certain specifiable conditions, the volume of a gas will vary inversely as the pressure exerted upon it," are verifiable in this direct manner. However, many hypotheses, especially the more general and fundamental of scientific laws, are verifiable only *indirectly*. The hypothesis must then be restated in such a manner that there are inferable from it other propositions which, supplemented by certain mathematical and logical operations, institute data that verify the derived hypotheses. Thus the hypothesis that "The sun and the planet Mars attract each other proportionately to their masses and inversely as the square of their distances from each other" can not be confirmed directly by observation. But one set of consequences from this hypothesis, that the orbit of Mars is an ellipse with the sun as its focus, and that, therefore, given certain initial conditions, Mars should be observable at different points on the ellipse at certain times, is capable of being verified.

In any case, whether directly or indirectly, the hypothesis must suggest a definite operation of observation or of experiment, otherwise it is impossible to test and verify it. The hypothesis that

the universe is contracting in such a manner that all linear measures shrink in the same ratio is empirically meaningless if it can lead to no operation from which observable consequences follow.

(2) The hypothesis must also be *consistent*. For, as we have seen, a given experiment tests not only the particular hypothesis in question but also the body of hypotheses relevant to it. No hypothesis acquires cognitive status for science if the acceptance of it necessitates the surrender of other hypotheses already accepted as scientifically well grounded. Thus the hypothesis that "God created the world during a six-day period some thousands of years ago" is inconsistent with a large number of hypotheses now accepted as commonplace truths in natural science. Thus the hypothesis that "Light waves or corpuscles are unaffected by gravitation" is inconsistent with differences recently discovered in measurements of the apparent position of a star when seen near the visible edge of the sun as compared to its position to the same neighboring stars when far removed from the sun.

Consistency, while a logical relation, in no way implies logical deducibility. Two or more hypotheses are *consistent* with each other when their respective meanings are such that *no one of them implies the negation of any other of them*. Thus the hypothesis that "The helium atom consists of one proton and two electrons," and the hypothesis that "Pleasure is the sole and constant object of human desire," are consistent with each other. Indeed, two or more hypotheses may be consistent with, yet logically independent of, each other. For two hypotheses are independent of each other when they are such that the truth or falsity of either implies nothing as regards the truth or falsity of the other.

Furthermore, a hypothesis must be consistent not only with the body of

accepted hypotheses, it must also be consistent with *all* the data (facts in the first sense) relevant to it. Precisely what data are relevant to a given hypothesis must be determined by the nature of the hypothesis on the one hand, and by the character of the data on the other. For example, a man is found dead in a room. Suppose it be decided that he came to his death by a gunshot wound in the head such that death must have been near-instantaneous. Suppose also that no weapon can be found on the premises and that signs of a struggle are in evidence. The hypothesis of "suicide" is then inconsistent with, *i.e.*, it fails to explain, many of the relevant facts. Consider, to take another illustration, the nebular hypothesis of Kant and Laplace. For a time this hypothesis seemed to account for the motions of all the then-known bodies of the solar system. However, with the discovery of the retrograde movement of the eighth moon of Jupiter, another and relevant fact intruded which could not be accommodated to the hypothesis, in consequence of which the hypothesis was seriously questioned.

(3) Lastly, a hypothesis should be as *simple* as possible; or, if two or more rival hypotheses seem equally well to account for the facts, then, other things being equal, the simplest of them is the truer. By simplicity is meant *logical* simplicity; one hypothesis is simpler than another, not because it is more familiar or more easily learned than the other, but only when the number of independent elements contained in it are fewer than those contained in or implied by the other. Thus the concepts of plane geometry are simpler than those of solid geometry, because the former involve configurations in but two dimensions whereas the latter involve configurations in three dimensions. Thus the law of gravitation is simpler than the Ptolemaic

system of concepts, since the latter postulates a special hypothesis to account for each of the apparent motions of the bodies of the solar system.

Simplicity possesses also a second meaning. While two hypotheses may both account for a given domain of facts, one may account for a wider range of facts than the other. The former will then be simpler than and, therefore, preferable to the other. Thus the heliocentric theory, especially as developed by Newton, is systematically simpler than the theory of Ptolemy. We can account for the succession of day and night and the seasons, for solar and lunar eclipses, for the phases of the moon and the interior planets, for the behavior of gyroscopes, for the flattening of the earth at the poles, for the precession of the equinoxes, and for other events, in terms of the fundamental concepts of the heliocentric theory. While the Ptolemaic system of concepts can also be made to account for these phenomena, special hypotheses must be postulated in order to explain many of them, and many of these postulates are logically independent of the type of order taken as fundamental.

Indeed, it is this systematic simplicity which is sought in advanced stages of

scientific inquiry. Unless we remember this, many changes now taking place in science will seem arbitrary. For changes in theory are often made for the sole purpose of finding some more general hypothesis which will explain what was theretofore explained only by two or more independent hypotheses. This is the chief advantage of Einsteinian over earlier hypotheses in physics. When it is declared that we should prefer the simpler of two theories, it is always systematic simplicity that is meant.

Yet it is often difficult and sometimes even impossible to differentiate between the relative systematic simplicity of two hypotheses at an advanced stage of scientific inquiry. Is the Schrödinger wave theory more or less simple than the Heisenberg matrix theory of the atom? In case we can not decide, we must allow for an irrational esthetic element in our choice between them. But while there is thus an element of arbitrariness in our choice between rival theories, the arbitrariness is limited, for the theory chosen is still subject to the other criteria of verification. Only in those cases where *all* criteria fail us can we truly say that the rival hypotheses are all equally verified or unverified and hence are equally probable.

# GALILEO: PIONEER IN PHYSICS<sup>1</sup>

By Professor HENRY CREW

DEPARTMENT OF PHYSICS, NORTHWESTERN UNIVERSITY

FIFTY years ago this month, a highly interesting group of scholars gathered in the city of Padua. The occasion was the three hundredth anniversary of Galileo's first lecture before the already ancient university of that city. Delegates were present from the leading intellectual centers of Europe. Cambridge University was represented by Sir George Darwin, son of Charles Darwin, the great naturalist, and father of Sir Charles Darwin, now director of the National Physical Laboratory. Honorary degrees were conferred upon such men of science as Helmholtz, Kelvin, Tisserand, Schiaparelli, and our fellow countryman, Simon Newcomb. The public addresses were in every way worthy of the man they celebrated—the last of the great Italians.

Naturally one's curiosity is aroused to learn just what any man could possibly have done in physical science three centuries ago to deserve such long remembrance. The answer to this question most of you know as well as I; some of you much better than I; for, in all the annals of science, no man has so often been tried before the public by historians and astronomers, as has Galileo. In the time allotted to me, I am hoping to say only a few words about the surroundings under which the boy grew into manhood, then a few more words about the mode in which he introduced the experimental and quantitative method, thereby creating the science of modern physics.

<sup>1</sup> From the symposium on "Natural Philosophy" commemorating the 300th anniversary of Newton's birth and Galileo's death which was to have been presented at the New York meeting of the American Association for the Advancement of Science. Other papers of the symposium will appear in later numbers of this magazine.

Let us step back just five short lifetimes of three score years and ten. We find ourselves at the close of the sixteenth century and near the end of Queen Elizabeth's reign. The first great wave of the Reformation has passed, but the final military struggle between the Catholics and the Protestants—generally known as the Thirty Years War—has not yet begun. This is the period when "divinity doth hedge a king," when natural science is limited to medicine and physical science to astronomy; when philosophy is still in the saddle and scholarship is confined to the clergy. The system of Ptolemy has been overthrown; but that of Copernicus has not yet been established.

It was under circumstances such as these that Galileo was ushered into this stormy world on the fifteenth of February, 1564, at the little city of Pisa. He had chosen good parents to be born of. The visitor in Florence who enters the large door of the church of Santa Croce finds himself standing over a marble slab covering the grave of a Galileo who had distinguished himself in medicine some two hundred years before the advent of his famous descendant. The father of our Galileo was no ordinary man. For he was well known, not only as one who did his own thinking, but also as a composer of madrigals, an authority on counterpoint, a skilful performer on the lute and a historian of ancient music. The originals of his more important works are to be found, even today, in our Library of Congress. Just now the father had fallen upon hard times; and was earning a scant livelihood for his family by giving music lessons.

It is not surprising that a lad, brought up with this background, should find himself a student in the University of Pisa at the age of seventeen. Here at the request of his father he enrolled as a student of medicine; and listened to the famous physician and botanist, Cesalpino. The major portion of his time was given to the doubtless dull task of reading what Hippocrates and Galen had said; but the boy's natural bent, towards mathematics and experiment, was too strong to allow him to pursue any farther the medicine of that day. And so, much against the wishes of his father, he shifted his attention to Euclid and Archimedes, designed a hydrostatic balance and played with the determination of certain centers of gravity. It was exactly at this time that Maurolycus published a beautiful Latin translation of the works of Archimedes, a volume which, we may be sure, Galileo eagerly devoured much in the same fashion in which our late friend and genial spirit, A. G. Webster, brought himself up on *Thomson and Tait* and then proceeded to write a much better book on the same subject.

These early mathematical studies, made in Florence, occupied a good part of the three years following Galileo's departure from the University of Pisa in 1585. And they served him well. For they not only brought him into contact with Father Clavio and the Marquis del Monte, two of the leading mathematicians of Italy, but they earned for him a lectureship in mathematics at the university from which he had so recently withdrawn—the university where he had just shown himself to be a radical in philosophy and a disputant of the first order. It was during this second period of his residence at Pisa that he took up the most serious pursuit of his life—the study of dynamics. Here he eagerly adopted the maxim of Aristotle which, in its medieval form, read *Ignorato motu*

*ignoratur natura*. Here also he displayed his faith in experiment rather than in peripatetic philosophy. There was no thought, even in these early years, of swallowing Aristotle whole. The famous demonstration at the Leaning Tower, about which so much has been written and so little known, also belongs to this period.<sup>2</sup>

What is most certain about these few years at Pisa is that Galileo's frank expression of opinion had made him *persona non grata* to some of his colleagues; so that he was happy to accept, in 1592, the chair of mathematics in the University of Padua—an institution which was, even then, older than Harvard University now is. His eighteen years in this renowned seat of learning were a period of uninterrupted success; "the happiest of all my life" he calls them.

His lectures at this time did not deviate much from those given in other Italian universities. His principal topics were *The Elements of Euclid*, *The Sphere*, equivalent to our astronomy, *The Almagest* of Ptolemy, *Fortifications*, *Perspectiva*, which we now call *Optics*, and *Mechanics*.

The Copernican system was then a recent invention. That it was well known to Galileo and was accepted by him is shown by his private correspondence. "Why then," you ask, "did he not lecture upon it?" One can only guess that a young man of 28 is not anxious to borrow trouble or to share such derision as had recently been heaped upon Copernicus. Kepler's *nova* which flashed out brighter than *Jupiter* in 1604 gave Galileo an excellent oppor-

<sup>2</sup> More than twenty years ago, Cajori and Partridge showed by careful search that, if Galileo ever allowed two bodies, one heavier than the other, to fall from this tower, neither he nor any one of the witnesses present has left the slightest written account of the experiment. Professor Lane Cooper has indeed written a hundred-page volume in order to establish a thoroughly agnostic attitude of mind toward all stories and pictures of this dramatic event.

tunity to break down the Aristotelian view of the incorruptibility of the heavens; but he exercised great self control and continued to expound the Ptolemaic system until the invention of the telescope in 1609.

One happy feature of academic life at Padua was that often a group of students working with some particular professor would live in the same house with him. Galileo lodged and boarded such a group of students. Some of these he employed in his workshop where his geometrical compass and other pieces of apparatus were manufactured. It is therefore, not surprising that, immediately after learning of the invention of a telescope in Holland, he should ask himself what the optical combinations must be; or that he should at once put together a plano-convex and a plano-concave lens into what we would now call a long focus field glass. Nor is it surprising that in rapid succession he discovered the mountainous character of the Moon's surface, the first four satellites of Jupiter, the "triple nature" of Saturn, the phases of Venus and the spots on the Sun. The year 1609—eleven years before the landing of the Pilgrim Fathers—will long be remembered not only for the invention of the telescope, but also for the announcement, by John Kepler, of his first two laws—laws which, in a certain sense, completed the geometrical theory of our solar system. The mention of Kepler's name reminds one of a surprising and unfortunate trait in the character (or perhaps in the mind) of Galileo. I refer to the fact that he never appreciated the monumental discoveries of Kepler.

The recent revelations of the telescope which Galileo had announced in the *Sidereal Messenger* were fraught with many long results of personal significance. First of these was a generous increase in salary. The second was a cordial invitation to return to his native Tuscany as Philosopher and Mathema-

tician to the ruling family—the Medici. Needless to say these two results were much more acceptable than the long train which followed.

In 1610 he returned from Padua to Florence where the remaining 32 years of his life were spent in observation, experiment and reflection, interrupted only by brief visits to Rome. The results of these labors are recorded, as you like, either in the splendid 20 quarto volumes of Favaro's National Edition or in Galileo's three outstanding books, namely, *The Saggiatore*, *The Dialogue on the Two Astronomical Systems*, and *The Dialogue on Two New Sciences*.

The distance between Florence and Rome is not very different from that between New York and Baltimore. Covered by train or motor car, it is merely a pleasant jaunt. But, for Galileo, who never set foot outside of Italy, in spite of the fact that he had opened the doors of the heavens and had roamed the universe, this journey was a considerable undertaking. He made the round-trip six times; each excursion being an event of such importance that the rest of his story may, perhaps be told in terms of these journeys.

I. An early first visit need not detain us; for it was made by the twenty-two year old student of mathematics in order to discuss with Fathers Clavio, Moletti and Valerio—three able mathematicians—certain problems upon which he and they had been working.

II. In the spring of 1611, our astronomer—now a mature man of forty-seven—made his second trip in order to exhibit to the pontifical court some of his newly discovered celestial objects. In Rome, he was the guest of the Tuscan ambassador at the Medici palae on the Pincian Hill. His telescope was set up in the nearby gardens of the Quirinal palace which was, at that time, the summer home of the Pope.

Here a group of able cardinals and

monsignori saw the mountains on the Moon, the phases of Venus, the four moons of Jupiter and, by day, the spots on the Sun. The result was that, within the next two years, Galileo was called upon, by men high in church and state, to explain the "evident" contradiction between Science and Scripture. His replies to all these queries are marked by one essential thought, namely, "The Bible teaches us how to go to heaven; not how the heavens go." Science and the Scriptures tell two independent stories. His own famous words are "*La scienza nè sopra nè sotto la fede, ma fuori della fede.*"

III. Again four years later, in December of 1615, we find him on his third visit to Rome, urged this time by the desire to clear himself of charges which two Dominican monks in Florence had made to the Inquisition. This time he was cordially welcomed and eagerly listened to by del Monte and Bellarmini, two important cardinals; but they gave him semi-official warning not to indulge in theology. In particular, he was advised not to "hold, teach or defend" the rotating earth or the fixed sun. Whether or not Galileo agreed to these conditions is not certainly known. In any event, this conference is generally known as his "first trial."

Rejoicing that no abjuration had been required, he returned to his home at Bellosguardo, a suburb of Florence, and entered upon a seven-year period of uninterrupted work.

IV. Then comes his fourth trip in 1624—about the time when the Pilgrim Fathers had fairly established themselves on the coast of Massachusetts. Father Grassi, a Jesuit astronomer in the Collegio Romano, had published in 1619 a small volume in which he opposed Galileo's theory of comets and indulged in violent abuse of its author and of his school. The object of this fourth visit was to publish, through the Academy of

the Lincei, a reply to Father Grassi. This reply, which he called *Il Saggiatore*, is a tremendously clever piece of polemic, abounding in wit and humor. It was dedicated to his long time friend, Cardinal Barberini, now become Pope Urban VIII. One can easily imagine how little a publication of this kind enhanced the credit of the Florentine astronomer among the Jesuits.

V. Six years filled with labor and illness now elapse before the fifth journey to Rome is undertaken. The work accomplished during this interval was the preparation and composition of the *Dialogue on the Copernican and Ptolemaic Systems*, which for elegance of style and clearness of exposition remains unsurpassed. The purpose of this trip was to obtain an *imprimatur* for this *Dialogue*. He travelled by court litter and was handsomely entertained on the Pincian Hill at the home of the Tuscan ambassador. His friend Urban VIII gave him not only six lengthy audiences but also a pension for his son. After long delay, the *imprimatur* was granted but only with certain humiliating conditions. The details are too long to be recited here. Suffice it to say that the book issued from the press at Florence in January of 1632. Its sale was prohibited in the following August.

VI. In October of the same year, the Inquisition summoned Galileo to Rome, where he arrived in February of 1633. Previous trips were easy when compared with this one which was his sixth and last; for it was made in midwinter by a man of three score and ten, in feeble health, carried in a litter which was perhaps none too gentle. Once more he was the guest of Nicolini the Tuscan ambassador.

The charge against Galileo, at this second trial, was of course that he had defied the command of the Holy Office. This command was that he give up his belief in the double motion of the earth,

that is, its rotation on its axis and its revolution about the sun. On the 22d of June, 1633—a memorable day—he was forced, under threat of torture, into the great hall of the Inquisition, attached to the church of *Santa Maria sopra Minerva* and was there made to read his recantation.

Many various opinions have been expressed, as you all know, concerning this recantation. My guess is that Galileo wisely acted upon the advice of his friend and host, Niccolini, who urged him to accede to the orders of the Inquisition and to say to them, not in so many words, but virtually and in his own mind "Well, if *you* say that the earth does not move, it must be so! And there's an end of the whole matter."

Can anyone believe that this aged scholar, travelling along his *via dolorosa*, had forgotten what happened to that courageous soul, Giordano Bruno, when, only a few years back and only a few city blocks away, the flames consumed his poor body? Does anyone imagine that Galileo had forgotten his first love among the sciences? Is it possible that the unfinished work on dynamics, upon which he was to spend the remaining years of his life, had completely slipped his mind? He had given the Inquisition a respectful acquiescence; but the matter of inner assent was his own affair. Obviously he was neither hero nor martyr of science in the ordinary acceptation of those terms. I like to think of this second trial not as a battle between science and religion but as a contest between science and Aristotelianism. I entertain also a high respect for that ancient Chinese proverb which maintains that a wise man adapts himself to circumstances as water shapes itself to the vessel which contains it.

July of 1633 finds this lonely man starting north again defeated but undaunted. This time he stops on the way, at Siena, to spend a few months with

his trusted friend, Archbishop Piccolomini. So that it was not until December of 1633 that he completed his last trip to Rome and reached his little villa at Areetri where, in strict seclusion, he spent the years that were left.

But these years, during which the greatest living man of science was confined at home by decree of the Holy Office, as well as by illness and by old age, make up one of the remarkable periods of his life. "Here it was," says the young Milton just out of Christ's College, Cambridge, "that I found and visited the famous Galileo grown old, a prisoner to the Inquisition for thinking in Astronomy otherwise than the Franciscan and Dominican licensers of thought." Here in his declining years, not many yards away from the little convent of San Matteo where his two daughters had taken the veil; here where nearly all his family had perished in the recent plague; here, in humiliating and discouraging circumstances, he takes up the science to which his early years were devoted, the science to which his contributions showed the highest originality and the utmost importance.

His interest in mechanics, which appears to have been life-long and unbroken, culminated in the *Two New Sciences*—the work for which he will probably be longest remembered. The entire volume is based upon the assumption that terrestrial and astronomical phenomena are to be explained in mechanical terms—an assumption which has been out of date since the close of the nineteenth century, but one which many twentieth century physicists admit to have been helpful in its day.

Harry Lauder, you know, insists that World War No. 1 was won mainly by the Scotch regiments, but admits that the French, English and Americans rendered important assistance.

This last book of Galileo's is in the form of a dialogue which offers great

freedom to introduce new topics and permits the easy give-and-take of an after-dinner group in a club corner. The early part of the work is devoted to what we now call strength of materials, bending moments of beams and digressions upon such various topics as the harmonies of the major chord, the definition of an infinite quantity and the velocity of light. So far as I have been able to learn, his picture of an infinite quantity, as one which is so large that a part of it can be placed into a one-to-one correspondence with the whole of it, is original and also basal to the later and more complete view of Cantor, Bolzano and Dedekind. His method of measuring the speed of light by sending a luminous pulse to a distant observer to be returned by him is of course valid only in principle; but the principle is precisely the one which was so admirably perfected by Fizeau and the late Professor Michelson.

The latter part of the book is given over to a description of what was then known as "local motion"—a striking term which harks back to ancient days when *motion* meant change; and hence *local motion* meant change of *position*. The idea appears to survive in our word *locomotive*. Galileo aims to describe only those motions which occur in nature; so he begins with freely falling bodies; "dilutes" gravity by use of an inclined plane; proves by experiment the constancy of gravity for a bronze ball; and then by use of a hollow pendulum establishes the remarkable fact that gravity is constant for all substances. *Uniformly* accelerated motion having been identified with *naturally* accelerated motion, the other laws of falling bodies follow easily and immediately.

The vector idea he introduced into mechanics by use of the inclined plane; and by comparing the *increasing* momentum of a body rolling down such a plane with its *constant* momentum as it

rolls along a horizontal plane, he distinguished between the behaviour of a body which is acted upon by a force and of one which is free from force. He thus led directly to our modern definition of force as the rate of change of momentum. But the idea of a body under no force moving with uniform momentum is, of course, nothing else than Newton's First Law of Motion. His introduction of time as a variable which can be measured and represented by a distance laid off on an axis is, so far as I know, an entirely new and important step.

The last chapter of the *Two New Sciences* is devoted to the motion of projectiles. The maximum range *in vacuo* is quickly established as one having an elevation of  $45^\circ$ ; but most important of all is his remark that "such motions and velocities as these combine without altering, disturbing or hindering each other." This statement is such a close approximation to the second law that Newton, in the *Principia*, distinctly credits Galileo with the discovery of the first two laws of motion, reserving for himself only the third. Galileo's complete abandonment of all metaphysical considerations, his refusal to ask *why* bodies fall and his insistence upon discovering *how* they fall has made this Italian physicist a model for all subsequent investigators.

In conclusion it may be said that the science of mechanics owes to this pioneer not only the first two laws of motion but also the modern definition of force as the rate of change of momentum. Just how new and radical these ideas were can be conceived only by one who has acquainted himself with the then current peripatetic notions on the same subject.

The distinction between *mass* and *weight* was a later step, reserved for Huygens. *Impulsive forces* and *tides* were also beyond the ken of Galileo. These two puzzles were first robbed of their mystery by Galileo's great suc-

cessor whose birthday is being celebrated this year.

In this connection, may I say that the contrast between Newton and Galileo is not altogether pleasing. The Italian was born under circumstances which bordered on poverty and spent his boyhood in the narrow confines of the city; the Englishman began life in affluent surroundings and roamed freely over the lovely countryside of Lincolnshire. The one found a university career possible only by the endurance of great privation and left it incomplete because of unpleasant associations; the other enjoyed fellowship and freedom, companionship and comfort in one of the leading institutions of his country. The one found his work opposed by the church and plagiarized by his fellow countrymen; the other was rewarded by a distinguished professorship and honored by political preferment. Late in life one is still hounded by the church; the other

is elevated to the presidency of the leading scientific academy of the world.

Yet, with all these odds against him, Galileo spent his life in the study of motion, a subject which had been left untouched by his great predecessors, Euclid, Archimedes and Apollonius. The path which our pioneer cut through the forest, 300 years ago, was precisely the one followed by Huygens and Newton—the one which led unerringly to that field which is now cultivated under the name of physical science.

Responsibility rests upon science as never before. In our present crisis we depend mainly upon physics and biology. Our fate is in the hands of the young manhood of the United Nations. They are employing three great powers *science, economics and politics*. Can anyone doubt that they will reestablish the freedom of international thought and individual enterprise in both hemispheres?

## VISION, HEARING AND AERONAUTICAL DESIGN

By Commander LEON D. CARSON, Professor WALTER R. MILES  
and Dr. S. S. STEVENS

MEDICAL RESEARCH SECTION, BUREAU OF AERONAUTICS, U. S. NAVY; YALE UNIVERSITY SCHOOL OF MEDICINE; HARVARD UNIVERSITY

IT is principally through the sense of vision that pilots are aware of the nature of terrain, weather conditions, the terrestrial orientation of their aircraft, and the position and movements of enemy planes. Even so-called "blind flying" is primarily a visual function. Here the "contact" is transferred from the horizon and ground objects to the special instruments upon the panel. Hearing likewise is of critical importance to military flyers in that command information and assistance from ground control stations must be audible over the communication system. Also intercommunication

systems within aircraft must function as the principal means of maintaining prompt and coordinated action of members of air crews in carrying out military missions effectively. These facts are generally known and accepted by plane designers. However, engineering success in providing for ease of seeing and ease of hearing is quite variable, and these basic pilot requirements merit our continued attention.

Take, for example, the almost complete blanking off from vision of an area directly ahead of the pilot when a plane changes its normal flight attitude to a

landing attitude. This is particularly vicious in the case of fighter aircraft with large air-cooled engines in the nose of the ship; and the condition has resulted in a great number of avoidable landing, taxiing, and take-off accidents. Aircraft carrier accidents have undoubtedly resulted from this blanked off area, in spite of the fact that a landing signal officer is supposed to direct the landing properly. Mirror reflections of the area immediately ahead of the plane could be provided. Tricycle landing gear on some few aircraft have done much to benefit this blindness due to radical change in plane attitude.

Engineers are no doubt aware of the desirability of placing pilots, observers and gunners as near as possible to the transparent panels through which they must get their visual impressions. The nearer the eye is to the window, the larger the visual field that can be seen through it, or for a given angular field, the smaller the window needed. The ordinary spectacle lens one and a half inches in diameter gives the wearer an uninterrupted view of almost 90°. Close proximity to airplane windows also makes for clear visual fields; (1) it is easier to provide the requisite transparent area free from obstructing pillars, panel joints, and opaque accessories; (2) marks, specks, and scratches on the window surfaces are less bothersome because they are out of focus; and (3) when near the window, the observer's head makes an area of shadow which is helpful, particularly at night, since it blocks off reflections from the inner surface.

#### THE GUNNER'S VISUAL PROBLEM

The position of gunners in relation to windows is especially worthy of consideration. We may take a hypothetical set of measurements for discussion. The gunner's eye must be about nine inches behind the gun sight; the sight is twenty

inches from the aiming panel; the gunner's seat is therefore placed against the back wall of the turret, and the space in front of him is well filled with gun supporting and operating structures. The aiming panel is a beautifully clear, optically perfect surface 14×14 inches. The engineers are to be congratulated on this window, but not on the position of the gunner. For him the situation resembles that met in tunnel vision. His eyes are 29 inches away from this superb window which can provide him with a view of only 28° of the full 60° to 90° that are so critically needed.

The aiming panel must of course be well mounted, and this calls for a rather heavy metal frame. Sometimes it is as much as two inches wide. Other small, usually curved windows border the aiming panel, and each of these must have or share a frame with adjoining windows or wall structures. When the guns are in front of the gunner, sections of the mounting structure, brackets, electrical switches, etc., frequently have locations which obscure portions of the windows from the gunner's eyes. The total effect is a lattice window with the lattice predominating over the clear space in some instances. From the gunner's view, through a particular panel, a total of only 25 per cent. is unobstructed to binocular vision; 53 per cent. is totally obstructed; 22 per cent. is obstructed for one eye. Juliet could manage to get an eye full of Romeo through a lattice window, but our gunner is not cast in the role of a shy lover. For him the irregular lattice is a hazard to vision and life. It is true enough that through the lattice he can see a lot of landscape as he looks from one opening to another. What he needs to see, however, is moving planes. When his eyes catch sight of one, they try to follow it. This is done by a special kind of coordination in the action of eye muscles and is known as pursuit eye movement. The eye actively

glides along at a rate set by the visual target and appropriate to keep it in clearest possible view on the fovea. Visibility of the moving target is essential for this type of seeing. Whenever the moving target momentarily disappears, as happens when it passes behind opaque lattice areas, the pursuit movement is immediately stopped. The eye jumps to the far edge of the obstruction and waits. When the target emerges, a new pursuit movement must be organized by the nervous system. This necessarily costs an average delay of fifteen hundredths of a precious second before clear pursuit vision can be reestablished. The gunner is of course not completely blind during this interval, but his visual efficiency on the moving target is hampered by every opaque gap across which he is compelled to operate.

In turrets where the guns may be mounted at the sides and rather low down, it should be possible to reduce the amount of structure in front of the gunner and to bring him forward much nearer the front panel. This will increase his angle of uninterrupted view, make visual pursuit of his targets easier, and reduce the blinding effect from the flashes of his own guns.

#### VISION INSIDE THE COCKPIT

Inside the cockpit we usually observe a confusing multiplicity of instruments and the lack of a suitable grouping of essential flying instruments according to a well planned pattern for visual perception. For purposes of night flying where visual function is largely dependent upon maintenance of dark-adaptation of the eye, instrument panels in general are subject to the following serious faults:

- (1) There is too large an illuminated area. Instruments which are referred to infrequently are constantly illuminated.
- (2) The color of the transmitted or reflected light from these instruments is

usually not of the spectral band least disturbing to night vision.

(3) Intensity as well as total area of illumination is considerably too high. This is usually a criticism equally applicable to direct or indirect lighting, radio-luminous, or fluorescent marked instruments. The only light which can be controlled easily both as to spectral character and brightness level is indirect red light. The use of a spectral red whose transmission band lies in the region of 600 millimierons is recommended for instrument lighting. The intensity of such light may be permitted to vary considerably without adverse effect upon night vision.

Transparent cockpit enclosures, although of fairly clear optical plastic, discolor with exposure to sunlight; some of them become finely checked due to temperature changes and vibration. Nearly all of them are capable of being scratched too easily, and the result is interference with vision. Measurements of visibility through plastic windows, compared with bullet-proof glass and with open cockpit view, show that the glass produces a slight loss and that the loss from the plastic may be five or six times as much. Flat panes consistently provide better visibility than do curved plastic surfaces, but they may also give an increased drag. A compromise must be made between visibility and aerodynamic considerations. Rapid strides in development of better plastics are being made, and it should be possible soon to mold transparent cockpit enclosures of better grades of optical plastics in one piece. Surface hardening of such molded parts is desirable. Close attention should be given to reducing inside reflections which are particularly troublesome from concave surfaces.

In military aircraft we often find that vision forward and to either side is fairly well provided for but that even though the pilot may have the usual

well-developed rubber neck, he is handicapped by certain design features of his plane in seeing what may be above or aft. It is often forgotten that in actual combat pilots refuse to leave the "greenhouse" closed and must therefore use goggles. Any fixed aperture made available for the pilot's face should not be too small to permit use by a bespectacled or goggled aviator.

#### AIRSICKNESS AND VISION

Airsickness of passengers and crew may result from unavoidable motion stimulation of the vestibular mechanism of the ear, from rapidly changing gravitational forces acting on viscera, muscles, and joints, and from apprehension and past unhappy memories of plane travel. All of these upsetting stimuli are as a rule less disturbing if those affected can see out and establish visual contact with the horizon, with cloud formations, and with the ground scene below. We should remember the old instructions to novices in flying, "Never look at the up wing; watch the down wing." Many troop-carrying glider craft afford virtually no opportunity to look out and establish visual contact beyond the plane. To arrive at the scene of battle with a load of thoroughly ill troops contributes nothing to fighting morale and effectiveness. A part of the answer to this difficulty is—don't require passengers and crew to fly blind.

#### HEARING SUFFERS MORE THAN SIGHT

The ears more than the eyes are subjected to environmental stress through flying. It seems to be true of modern aviation that every time the engineers increase the power and speed of our airplanes, the ears of the pilots take a greater beating. Although the ear is a magnificent little mechanism—the most intricate mechanical structure in the human body—it is a rather delicate device and one which seems ill designed for

modern war. But the ear has gone to war, along with the rest of the soldier, and we are compelled to admire the service it renders in the face of acoustic stress.

Airplanes have always been noisy, and they are becoming noisier. A thousand horsepower fed into a propeller is able to agitate the atmosphere in a thunderous manner, and when the engine delivers two thousand horsepower the din is doubled, or actually more than doubled, because as the tip speed of the propeller increases a larger proportion of its driving energy is converted into sound. When this energy pounds on the ear, it is striking a mechanism so sensitive that less than one quintillionth of a horsepower is needed to produce a faint sensation of hearing. In addition, more horsepower means more speed and hence more turbulence about the ship. It is this turbulence of the slip stream over the wings and about the fuselage that produces the distressing, high-frequency random noises which sound like a mighty "shhhhhh." In some respects the noise from the turbulence about the plane is more of a problem than is the noise from the propeller itself. This is demonstrated in planes which do not have propellers. Contrary to popular notions, the interior of a glider plane moving at about 150 miles per hour is a very noisy place. The noise level is about 115 decibels, and conversation in such a place is difficult, if not impossible.

In any really fast moving vehicle the noise is random, that is to say, all frequencies of the spectrum are present. When we listen on the ground to a plane high overhead we hear only the low frequencies of the propeller. But inside the plane it is different; there we hear all frequencies added together at once, producing a noise which is to sound what white light is to light. And as a general rule, the greater the speed, the "whiter" the noise. Also as a general rule, the

whiter the noise, the more objectionable it is to the ear. "White" noise is objectionable for three reasons: it is disagreeable, it produces temporary deafness, and it spoils communications.

That white noise is annoying needs little argument. No one has been found who really enjoys it. It is true, however, that our attempts to prove that long exposure to intense airplane noise is damaging to human efficiency have produced essentially negative results. When adequately motivated, a man can code a message, add columns of figures, coordinate his movements, react to a signal, etc., about as well after eight hours in a noise of 115 decibels as after a similar period in the quiet. Despite this remarkable experimental result, our subjects all report that they find the noise unpleasant, and they are happy when it is turned off.

#### TEMPORARY DEAFNESS

That airplane noise produces deafness is a well known fact. In normal ears this deafness shows two characteristics: it is restricted more or less to the high frequencies, and fortunately, it is usually temporary. After eight hours in an airplane noise of 115 decibels, the normal ear shows a hearing loss of about 40 decibels in the region of 4,000 cycles. It has sometimes been supposed that low-frequency airplane noise produces high-frequency hearing loss. On the contrary, it is the high-frequency components of the noise that produce the high-frequency loss. The ear, for some unknown reason, is more vulnerable at these high frequencies.

Recovery from a 40-decibel hearing loss usually occurs in about 24 hours. The recovery is rapid at first and then proceeds more slowly. About half of the loss is regained by a normal ear in the first three hours after exposure. Some ears apparently do not have this power of recovery, and repeated exposure to

noise leaves them permanently deafened. Although we usually blame the noise for such deafness, there is a question as to whether the ear itself is not the real culprit. At any rate, many ears appear to develop high-frequency deafness without excessive exposure to intense noise.

#### IMPROVEMENT OF COMMUNICATIONS

The most important practical effect of airplane noise is the masking of communications. Not only is conversation impossible in some planes, but even over radio and interphone speech signals are often masked beyond recognition. Articulation tests have shown that with much of our standard military interphone equipment a listener is able to understand only about 50 per cent. of the words spoken in the presence of an airplane noise of 120 decibels. Over the same interphones more than 95 per cent. of the words are understood when there is no ambient noise present to interfere with the speech.

The difficulty of communicating under the handicap of airplane noise calls for vigorous remedies. Constructive measures can be applied in three general directions:

First, the plane can be quieted to some extent, either by improved aeronautical design or by the application of sound absorbent materials. Acoustic treatment that is light enough to be tolerated in a plane does not appreciably reduce the overall noise level. It does, however, change the spectrum of the noise by reducing the intensity of the high-frequency components. Hence the noise in an acoustically treated plane is less "white" and therefore less bothersome than the noise in an untreated plane. Tests have shown that, for the same overall sound intensity, conversation person-to-person is relatively easy in a treated plane but quite impossible in an untreated one.

The second remedy calls for an im-

provement in the response characteristics of the communication equipment itself, especially of the microphones and earphones. A loud noise does not interfere with intelligibility nearly so much when instruments of high fidelity are used. But with microphones that have non-linear distortion and with earphones that at some frequencies are sharply resonant, the effect of an airplane noise of 120 decibels is to reduce the intelligibility of speech by 30 to 40 per cent. High-fidelity equipment is not yet being widely used in airplanes, although a few major improvements are now in process. Complete overall high fidelity from microphone to earphone must be achieved if speech is to be transmitted to and from our most modern airplanes.

The third remedy called for by the noise problem is the shielding of the microphone and the earphones from the noise. The oxygen mask could be so designed as to shield the microphone from the ambient racket, but many otherwise excellent masks suffer from acoustic defects. This problem is now under study, and improved noise shields for hand-held microphones are being developed. The earphones and the ear of the listener can be shielded from the airplane noise by means of an acoustic socket designed to provide a tight seal against the side of the head. In present military equipment this provision has been neglected, but improved devices are now in production. Some of these ear protectors serve to reduce the unwanted sound in the aviator's ear by 20 to 50 decibels.

#### CONCLUSIONS

In general, it can be said that the problems raised by intense ambient noise are serious but not insoluble. Ju-dicious use of sound treatment in the

plane, conversion to high-fidelity microphones and earphones, and the development of acoustic devices to shield the mouth and the ears of the personnel will permit the aviator to carry on in the best noises which the aeronautical engineers are now planning to produce.

The flying and efficient fighting of modern planes is largely dependent on the special sense of vision. The eyes fortunately suffer no great decrement in function from the swift movement or high and changing elevation of the airplane. Vision is adequate to the basic task assigned to flying personnel. The chief difficulty is in providing for optimal visibility through the structures of the plane and for continuous visual check on the environment surrounding it in both day and night flying. Ideal visual conditions are not wholly attainable because of aerodynamic and structural necessities. However, we should make the effort to gain all possible visual advantages. The problem is a continuing one and offers important strategic possibilities.

Both seeing and hearing, if accompanied by prolonged attentive effort, especially under conditions of unfavorable plane design, are capable of contributing to pilot and air crew fatigue and loss of efficiency. It has been proved worthwhile to give the airplane engine an adequate combustive mixture by super-charging and to pay special attention to protecting the oil in the engine against "foaming" at high altitudes and reduced barometric pressures. It is proving and will prove worthwhile to consider the flyer's eyes and ears and the rest of his very mortal body and to reduce in every possible way the tendency to physiologic and psychologic "foaming" in him.

## MEDICINE AND THE COMMUNITY

By Dr. LEO LOEB

EMERITUS PROFESSOR OF PATHOLOGY, WASHINGTON UNIVERSITY, SAINT LOUIS

ALL human beings face the struggle with nature for the material goods necessary for the maintenance of life, bodily health, and the avoidance of pain and premature death, for the understanding of the physical and biological laws underlying the interaction between organisms and their environment, which in the widest sense comprises the universe. But in addition, they face difficulties and obstacles in their social life, in competition with other human beings for material and psychical goods, in conflicts between different systems of tradition, suggestion and thought. Thus they have to face not only the natural struggle, but also the social struggle, and the latter is perhaps the more subtle and far reaching one as far as individual satisfactions, happiness or unhappiness are concerned. Here, they face the mental pain caused by doubts as to their justification or guilt in these conflicts, caused also by the suffering they avoidably or unavoidably inflict on others and the suffering which is inflicted on themselves, and here too they face the necessity of maintaining their personality in balance with that of others.

Confronted by the social struggle, the investigator in the biological and medical sciences, like other human beings, cannot help but make observations and in a certain respect even carry on experiments in regard to the more general problems of living, which affect him both as an individual and as a social being; indeed life itself is but a series of consecutive experiments. However, not infrequently one meets eminent men of science who doubt the advisability of students of the exact physical or of the experimental biological sciences of giving their attention to the analysis of social phe-

nomena in which the accuracy of the more basic sciences can apparently not be achieved. But our observations and conclusions here, as in the more exact sciences, may be true or false, and the criteria which are used for testing the truth are the same as those used in science.

There are others who are critical of such studies, because they may lead perhaps to the formulation of abstract principles, playthings of the mind, but are quite incapable of meeting directly the pressing needs in our social life. Yet true thoughts, even if they are not directly applicable to practical life, may be useful in suggesting directives for further thoughts, which ultimately will find application in daily life and which then will perhaps be found more far-reaching in their effects than the short cuts to near-ends desired by the more practically minded person. It may be that medicine, whose primary function it is to procure health, to delay death, and thus to aid man in his natural struggle, may take a leading part also in bringing about a mitigation of the severity of the social struggle.

Medicine in the course of time has dissociated itself from magic and has become an applied science of physiology, biochemistry and pathology. But it has progressed further: making use of psychology, it now treats the individual as a whole, his body as well as his mind. The interests of medicine continue to expand; the physical and psychical aspects of individuals can not be separated from their social background, from their customs, traditions, standards of social judgment and economic conditions. Medicine, therefore, includes in its sphere of inter-

est also sociology and makes use of the data this science has secured. And seeing further into the future, there may perhaps be a time when the physician will become the statesman, who, with the help of the engineer and economist, will direct the policies of whole communities, national and international, and when the statesman will essentially be a physician whose task it is to attend to the physical and mental health of the community. Thus medicine will be the science of man, applied to the maintenance of his physical and mental health, and it will then become evident that the problems of statesmanship will, to a considerable extent, be the same as those with which the physician has to deal in taking care of the individual; the statesman will, however, deal with the problems of the larger communities.

Such an extension of the function of the physician presupposes that it is possible to understand and in some degree foresee the action of individuals and of groups of individuals. But there are several criticisms which science in general, and medicine in particular, has to meet in this respect. It has been maintained that the action and attitudes of human beings are determined primarily by their genetic constitution and that inasmuch as no two individuals have the same genetic constitution, the actions of human beings cannot be foretold. Moreover, past experiences, which likewise influence human actions, differ in each individual. A science of human attitudes which could be practically applied, could not, therefore, be created. This conclusion is strengthened by the suspicion that knowledge in itself of a thing or relation will alter our attitude toward the latter and this again would render our actions unpredictable.

These arguments are not valid. All our bodily functions and structures are determined by genetic factors, yet we have been able to go very far in gaining an understanding of the structure and

function of organs and tissues, as well as of the whole organism. Besides, it can be shown that human actions and attitudes, at least as far as they are of social significance, are to a great extent determined by environmental, psychical factors rather than by genetic factors, and that experiences, while different in each individual, consist in all of them of similar social-psychical elements. It is the suggestions which we received especially in our childhood, by means of words or actions from persons who impressed us deeply, or from those with whom we associated in play or study, which greatly influence our attitudes even in later life, and these potent suggestions, after all, are restricted in number and in kind. Thus we may expect that the more we study the behavior of individuals the more we shall find in it a certain lawfulness, the more we shall recognize the existence of definite types and combinations of types and of situations which make possible predictions as to the motives and probable actions under a given social environment, and the more we shall learn how these actions may be influenced and modified. As to the manner in which knowledge of a condition affects our attitude towards the latter, even this appears to be subject to precise laws, which it will be possible to formulate and make serviceable in everyday life.

But there is another objection which applies specifically to medicine. It has been maintained that medicine instead of improving the human species by creating a better stock, on the contrary, causes its deterioration by nurturing the weak and inferior beings and allowing them to propagate. Further, it has been said that science in creating an industrial civilization and making possible the production of luxuries and rapid means of communication, has softened the individual and rendered him less hardy and less able to withstand the hardships of life; it has made him super-

ficial, nervous and discontented. As to the criticism that the practice of medicine causes a deterioration of the human stock, no proof of this has been given; if it has occurred at all, the proof that it is due to the nurturing of the inferior members of the human society could be given only after elimination of unfavorable environmental factors. In regard to the breeding of a superior human race, it seems that medicine, as well as biology in general, faces a very complex problem. A human individual is a mosaic of an extremely large number of constituent parts, each of which may be inherited in its own specific manner. Some of these constituents determine physical functions of various kinds, which make for strength and resistance to disease, while others make for various types of weakness and physical inferiority, and the same complications exist in regard to mental and moral determiners of the individual. Back of the obvious advantages and strong points seen in an individual there may be hidden undiscovered shortcomings, and in a pattern in which inferiorities are quite patent there may be some fine and most desirable qualities which are not recognized. It is easy to breed race horses, good milk cows, chickens for egg laying; the selection is made here not for individuals that excel all around and have worth in their own right, but for a single separate characteristic, chosen by members of a strange, dominating species for their advantage. There is a further difficulty. Many of the less advantageous genetic factors are recessive and hence are covered up in persons who appear to have a good constitution. These individuals therefore continue to transmit these unfavorable characteristics to their offspring and the prevention of breeding by those in which the undesirable character becomes manifest would not very noticeably diminish the frequency of its occurrence among the remaining population. Furthermore, even

if we were able to breed human beings selectively, it should be done not merely for the purpose of propagating the most perfect physical specimens, but especially with the view of creating beings sensitive to ethical values and capable of intellectual attainments. And lastly, by applying crude methods of breeding, similar to those used in animal breeding, there is the danger of lowering the significance of the individual and of psychical values which are of the greatest importance to all, and this might entail a depreciation of ethical standards more than offsetting any benefit which could be obtained by such a policy. If we consider this problem from the point of view of the pathologist, the number of diseases or of physical and mental defects in which genetic determiners are concerned is very great. There are, for instance, hereditary elements in the etiology of tuberculosis, of cancer; of hypertension and other diseases of the circulatory system; of abnormalities of carbohydrate metabolism (diabetes) and other metabolic deficiencies; there are hereditary elements also in the etiology of a variety of defects of the nervous system—such as some types of epilepsy; of defects of the eye, as those affecting the power of accommodation; of defects of the ear, of the teeth, and of various other organs. Which of these shortcomings in the genetic constitution would justify limitation of propagation? Might not a consistent and strict application of eugenic measures reduce the number of persons thought fit for parenthood to a small minority of the population?

Still, it must be conceded that there are conditions where it would be in the interest of the individuals themselves and of their possible offspring, as well as of future generations, that these persons be prevented from propagating. No conflict exists in such cases between the maintenance of the dignity of the individual and the interests of the com-

munity, which is composed of individuals—the latter being the essential reality. The methods used for this purpose must be humane and understanding.

The objections to science, and indirectly also to medicine, mentioned in the second place, are a criticism of civilization as it has developed mainly within the last hundred years. Science has provided the means of building factories and of rapid communications. Much time has been added to our life; we can make use of all kinds of products, which should satisfy our needs to a greater degree than has ever been possible previously in human history; new forms of entertainment have been provided on a much larger scale than was ever thought possible. Yet, it seems that happiness has not increased correspondingly. Although it is the physical sciences which are largely held responsible for these injurious changes, still, medicine is responsible indirectly, insofar as it has apparently made little attempt to prevent them.

However, it is not the contributions of science and medicine which are to blame for the deficiencies and unhealthy conditions in our civilization. What they have contributed is good; but these gifts have not been used altogether wisely, and the biologist, and above all the physician, in the future should take it upon himself, by his advice, to guard against the unwholesome application of modern technical improvements and inventions, which result in a loss of individual health of mind and body. Ultimately, these are questions of individual and social hygiene and they all belong, therefore, to the sphere of interest of the physician.

Yet it cannot be denied that while our civilization has eliminated much that was crude and even brutal in human relations, it has also caused a loss of the satisfactions which simple and sincere relations to other human beings and a quiet enjoyment of nature provide, and

that there has developed much restlessness, an aggravated spirit of competition in all our activities, and consequently worry, jealousy, envy, intensified antagonisms and struggles, injurious attitudes affecting individuals as well as social groups and leading to intensified discontent and to loss of mental restfulness and poise. But, it is not only the technical advances which are responsible for these shortcomings in our civilization and for the decreased value attached to the simple psychical goods; they have merely aggravated something which has deeper roots in the organization of the individual and of the social groups.

In order to appreciate these difficulties, we may somewhat more fully discuss some of the conditions on which our bodily and mental satisfactions and, ultimately, therefore also our bodily and mental health depend. We wish to obtain material goods in order to maintain the life and bodily health of ourselves and of those depending upon us, and we also need simple and distinctive psychical goods in order to maintain our personality. The memories of the psychical satisfactions received from those around us, the principles of conduct transmitted to us, and the thoughts and emotions drawn from science, philosophy, literature and art, as well as our own thoughts and emotions based on our experiences and observations, constitute the store of our inner psychical goods. It is especially on the latter that the harmony, equilibrium and the strength of our personality depend as do also our initiative in thought and action, the absence of unnecessary fear and of undue suggestibility, the normal coordination of our muscles, and therefore the ability to give to others what is good in ourselves. In the end, all our bodily functions, such as those of the digestive and circulatory systems, are intimately connected with this psychical wellbeing. There are reciprocal relations on the one hand between the functions of the ner-

vous system and the endocrine organs, by which, in their interaction with the outer world, our psychical life is largely determined, and on the other hand the functions of our more elementary organ systems, the healthy action of the former influencing that of the latter and vice versa.

Simple psychical goods are the expression of understanding, appreciation and respect, of friendliness and affection which our fellow beings may give to us. They also consist in the peace of mind, poise and recovery from mental injury which we experience in the quiet of nature and in the wider thoughts and emotions given to us by science, literature, art and music; these ultimately are the expressions of the effects of nature and the doings of man on some minds which are peculiarly sensitive and which function as resonators. This need of simple psychical goods has its roots in our bodily organization, but added to these are our experiences, and the thoughts and emotions created in the natural and social struggle.

In contrast to the simple psychical goods the cultivation of distinctive psychical goods implies the accentuation of superiority or inferiority and of competition in human relations. There are distinctive psychical goods based on national and racial characteristics, fixed or modifiable and representing true or imaginary differences; there are others based on family and social caste differences; and a strong and, not rarely, destructive element of competition may enter even into the distribution of simple psychical goods, which thus are converted into individual distinctive psychical goods. As to the source and origin of our need for distinctive psychical goods, they also reach deep into our bodily organization; competition for distinctive psychical goods and states of superiority and inferiority are found in the social life of various species of animals. But what, in the social life of

animals, is largely fixed and only slightly modifiable by means of conditioned reflexes, in man is controlled by suggestions and thought processes and, therefore, is to a much larger degree, changeable and subject to that which impresses us as free will.

The various forms of distinctive psychical goods give us the enjoyment of our superiority over others, a sense of elevation of our personality picture and thus also compensatory satisfactions for losses which we necessarily experience in life. By elevating our personality picture over that of others, they give us a feeling of security in the social and natural struggle, they make us less accessible to the will of others and prevent the results of excessive suggestibility and fear. They are much more effective in these respects than are simple psychical goods, but they also tend to separate individuals and groups from one another, to bring humiliation to many and to intensify greatly the severity of the social struggle.

Without conscious forethought, the human mind has tended, and it still tends to convert all possible institutions, events, and human relations into sources of distinctive psychical goods; these in their various types it has craved even as it has craved stimulant or sedative substances which give, temporarily at least, the feeling of strength and freedom from fears and inhibitions. But as the use of the latter exacts a price, often far exceeding the value of the subjective temporary benefits derived from them, so, also, the use of distinctive psychical goods is essentially unhealthful; as stated it brings suffering to many and a reaction often sets in against those who display their real or assumed superiority. These distinctions are employed as instruments in the strife which is constantly being waged for positions of mental-social superiority over others and in which a lowering and defeat of one means a victory and elevation for

the other. As secondary motives, this struggle has been introduced into all human activities, not only into business, but also into science, literature, art, and all other types of creative work. These accessory, subjective motives often exceed in strength the primary, essential and objective motives, those founded in the work itself, and rooted primarily in the struggle with the difficulties encountered in nature and they may greatly interfere with the satisfactions caused by real accomplishment. It is true that such motives, derived from the sphere of the social struggle, may also function as additional incentives to work, but they are essentially the source of the worries so often associated with work and thus they tend to cause depression and exhaustion, when even strenuous work as such would give satisfaction.

However, in different individuals the personality level desired and claimed varies very much, and accordingly also the nature and quantity of distinctive psychical goods claimed by them as their due vary, depending largely upon their upbringing and especially upon the suggestions they received in their early years of life.

In former times it was especially the feudal aristocracy whose right to a high personality level was recognized as valid. This is well and relatively harmlessly exemplified by the Duke of Somerset turning in anger to his second wife, who had tapped him playfully with her fan, and exclaiming, "My first wife was a Percy and she never dared to take such a liberty."\*\* To some extent such claims of the feudal aristocracy and their descendants are still potent today even in democratic countries, and in general, the criteria used in the distribution of distinctive psychical goods, in many respects are still derived from feudal times. But apart from this, every individual has built up a certain person-

ality level, which is determined by his individual experiences, by his sensitivity or expansiveness, and, also, by the grade which society concedes to him, according to his inherited or acquired social caste. This personality level, characteristic of each individual, greatly influences his attitudes and activities, into which his desire for distinctive psychical goods enters to a larger or minor degree. Likewise, the technique used by different persons in their attempt to maintain their own level or to reach a higher one varies greatly. Some rely almost solely upon their work and upon their helpfulness to others; some apply a social technique, which is well recognized by many, and which was succinctly stated by Lady Mary Wortley Montague with the words "Caress the favorites, avoid the unfortunates, and trust nobody."\*\* These latter persons may be inclined or ready, if necessary, to trade their thoughts, convictions, also truth and justice, as well as simple psychical goods and, even, their friends, for distinctive psychical and material goods which they greatly need in their desire for social advancement and power. In many others these two modes of social reaction are combined in various proportions.

If we now turn from the individual life to the actions and policies of larger groups, such as nations, in principle the same factors are active here as in the former, although with some modifications, which are due to the importance of mass suggestion in the life of groups and in the relative preponderance of the economic, material interests which are shared and understood by the large majority of the members of a group, in contrast to the psychical factors or motives which are of a more individualized nature and concerning which there might be a lack of agreement. However, there can be little doubt that also in international relations psychical factors play a significant role. The traditions of the

\* Cited by Louis Kronenberger in "Kings and Desperate Men."

people, the ambitions of some of the leading personalities, the suggestions, systems of thought and ideals potent in them have a large share in shaping national policies. Expressed differently, the need of simple psychical goods, the craving for individual, group or class distinctive psychical goods, and the nature of the inner psychical goods possessed by the dominating personalities also greatly influence national and international group relations.

While economic needs and interests are the primary factors in determining satisfaction and dissatisfaction with general conditions and in sensitizing people in such a way that they are ready for changes in policies, still the mode in which these attitudes find expression in actual life depends largely upon various psychical factors, and there is very little doubt that in the grave condition in which all the nations are today, these factors, elevations of the personality on the one hand and humiliations on the other have played an important part. In the end the significance of all the elements in our culture depends upon their content of psychical goods and on the contribution these elements make to our store of material, simple, distinctive and inner psychical goods and to their availability to individuals. Moreover, in the life of the individual and in the life of larger national and international groups, the total sum of energy used up in social friction caused by the competitive struggle for distinctive psychical goods is very great; this is a total economic loss and entails much waste of human happiness.

If we now return to the question which we raised as to the cause of social discontent, omitting the problems of adjustment in the production and distribution of material goods, which is the field of the economist, this is due at least in part to unsatisfied needs for psychical goods, and the latter again are at least partially caused by the planless manner in which

developments have taken place in the sphere of psychical goods in the past; as a result there have arisen abnormal and unhealthy valuations of different types of psychical goods and in particular an overvaluation of distinctive goods in various spheres of social life. These difficulties have been aggravated by the technical advances made in recent times, which tend to cause a still greater depression of the value attached to the individual and to simple satisfactions in social intercourse. In addition, the increase in individual liberty and initiative which democracy provides may have accentuated the evils of an excessive and sometimes ruthless competitive spirit in the field of distinctive psychical goods, which is contrary to the spirit of democracy and which in the end would destroy it. But these unfavorable results of the advances in the physical sciences and in the development of democracy are not inherent in science and in this mode of social organization; they can be separated from the latter and there is hope that they can be avoided. Besides the greatest possible security in the field of material goods there is needed the maintenance of individual liberty and initiative in our social relations as much as this is compatible with the equal needs of others. This implies as much as possible the avoidance of the injurious effects of inhibition and frustration in the functioning of our organism. But there is needed also for the healthy state of mind and body, the cultivation of friendly relations with our neighbors as well as with those farther distant. This requires the extension and intensification of our imaginative power, which enables us to see ourselves in all the others and all the others in ourselves. It also requires a planful limitation of the value attached to distinctive psychical goods and to their application in social life as well as a higher evaluation of the simple psychical goods. It requires the recog-

n the  
st; as  
l and  
types  
ar an  
n va-  
diff-  
tech-  
imes,  
de-  
e in-  
is in  
e in-  
initia-  
have  
and  
t in  
ods,  
noce-  
roy  
the  
l in  
not  
e of  
pa-  
ope  
the  
of  
in-  
as  
eds  
os-  
us  
in  
ut  
te  
of  
as  
is  
on  
es  
d  
re-  
s  
e  
nition of the dignity of the individual as the level of personality which is needed by every human being and which democracy will give to him. Important as the preservation of individual liberty and initiative is for the creation and maintenance of a healthy state in the individual and group life, we must keep in mind that they are not the only simple psychical goods that are needed but that the others must also be cultivated. However, in order to make such principles function in our social life, it is necessary to make their significance conscious in all members of communities and this requires the teaching of these principles and of the elements of social relations and of social technique in general to minds still young and plastic.

It follows furthermore from these considerations that the factors which will make the individual healthy in mind and body and which will insure the greatest possible security for his personality in the social and natural struggle, will ultimately be also the factors which will make possible rational relations between groups within the nations and between the different nations.

These conditions represent the essence of democracy; democracy is the mode of social organization which satisfies best the human needs of health of mind and body. In all other forms of social organization there is inherent the danger of a suppression of personality, of a lowering of individual initiative, also the introduction of differences in personality levels, which are based on artificial, unreal standards and which do not take into account the value and dignity of the individual; thus they tend to cause undesirable social cleavages and disturbances in the healthy social equilibrium. The principles of democracy must be applied in the life of the individual, in

the relations between groups within the nation, and they must be extended also to the sphere of international relations. This must be done consciously and planfully in the same way as other principles of public health are applied planfully, instead of being allowed to drift as they have been in the past.

The problems of the creation, distribution and function of psychical goods are, in the end, problems which concern the health of the individual and of the community and they belong therefore to the sphere of interest of medicine and of the physician in the same way in which the creation and distribution of material goods belong to the sphere of interest of the economist. Both the physician and the economist should be the guides whose advice directs the policies of communities within the nation and the policies in international groups. The physician will thus further the appreciation of the dignity of the individual as man's most valuable possession and he will be the guardian of democracy.

This is an important function, especially at the present time when democracy is fighting against a view of human personality and of life in general which tends to destroy all that is actually and potentially good in our civilization, and to replace the values of the free democratic life by brutal methods of suppression of the individual and of human individuality by a group chosen by themselves to be masters over all, contrary to human experience and to the teaching of science. Let us hope that this will be a passing phase in human history and that it will be followed by a time when science will enlarge and deepen our knowledge of the good life, and when man, and above all the physician, will help to translate this knowledge into actual living.

## THOMAS JEFFERSON—SCIENTIST

By Dr. JOHN W. OLIVER

PROFESSOR OF AMERICAN HISTORY, UNIVERSITY OF PITTSBURGH

THIS year, April 13 (April 2nd old style calendar) marks the two hundredth anniversary of the birth of Thomas Jefferson. Several studies will doubtless appear appraising his political, social, religious, and philosophical ideas. It seems appropriate therefore in this scientific age to call attention to Jefferson's interest in science, and the scientific developments of his time.

Jefferson was the most scientifically minded president this nation has ever known. "Science is my passion, politics, my duty" he wrote to Harry Inness. And to M. Dupont de Nemours, he wrote, "Nature intended me for the tranquil pursuits of science by rendering them my supreme delight." And again to Dr. Benjamin Rush, he declared that nothing but "revolutionary duties would ever have called me away from scientific studies." Had not these "revolutionary duties" driven him into politics Jefferson might well have taken rank as a scientist with Leonardo de Vinci, Francis Bacon, Sir Isaac Newton, and Benjamin Franklin. Even with all the political demands made upon him he still found time to render a distinct service in the fields of the physical sciences, mathematics, geography, botany, paleontology, agriculture, and natural history.

Jefferson's scientific activities fall quite naturally into five chronological periods. The first period ends in 1784 when he was sent abroad; the second relates to his scientific activities while in Europe, 1784–1789; the third period covers the years 1790 to 1801; the fourth period extends through his two presidential terms, 1801 to 1809; and the fifth relates to his years in retirement, from 1809 until his death in 1826.

### FIRST PERIOD, 1780–1784

In his *Notes on Virginia*, compiled during the busy years of 1781 and 1782, Jefferson demonstrated a rare gift of scientific inquiry. These *Notes* were prepared hastily to meet a special need. The French government had instructed Marbois, Minister in Philadelphia, to obtain accurate, statistical information concerning the different states. Marbois turned to Jefferson and asked him if he would prepare this information for Virginia. Jefferson was well qualified for this work. He states in his *Autobiography* that he had always made it a practice to keep careful notes on any information of the country "which might be of use to me in any station, public or private, to commit it to writing. These memoranda were on loose papers, bundled up without order. . . ."<sup>1</sup>

Marbois' inquiry caused Jefferson to put his *Notes* into proper order. It was a tremendous task. He had to do all his writing by hand. He took his *Notes* with him when he sailed for Paris in 1784, where he found he could have them printed for one fourth the price asked by the Philadelphia printers. Not satisfied with the results of the French printer, he next submitted them to John Stockdale, an English publisher. After they were printed he sent copies back to some friends in the United States.

These *Notes on Virginia*, according to the late Dr. G. Brown Goode, Assistant Secretary of the Smithsonian Institution, represent

the first comprehensive treatise upon the topography, natural history, and natural resources of one of the United States, and was the precursor

<sup>1</sup> Lipscomb, Andrew A. *Writings of Thomas Jefferson*; 20 Volumes; 1903–1905. II, Introductory Notes to Jefferson's Notes on Virginia.

of the great library of scientific reports which have since been issued by the States and Federal government. Though hastily prepared to meet a special need, if measured by its influence, it is the most important scientific work as yet published in America.<sup>2</sup>

To Jefferson, the study of natural history had a decidedly practical side. Plants and trees were put here for a purpose. He classified in minute detail the different types of vegetation found in Virginia. He divided the trees, plants, fruits, and all vegetation in four classes: the medicinal, the esculent, the ornamental, and those useful for fabrication. Besides the common names, he gave them botanical names, portraying the true character of a scientific, professional botanist.

His observation upon the climate of the mid-Atlantic region was far in advance of anything that had ever been attempted. The rainfall, temperature, prevailing winds, wind velocity were all treated in detail. The effect of sea breezes on salt making, the prevalence of sunshine, the seasons when frosts occurred and their effects upon plant life, all testify to the meticulous observations made by him.

No other early American has given such an accurate, detailed account of the rivers of Virginia and the upper Ohio Valley, of the mountains of Virginia and the Appalachian ranges. Jefferson detested generalizations. He insisted above all else on exactness; statistics were of value only when they were accurate.

One of Jefferson's most interesting scientific investigations, led him to contradict Buffon, the celebrated French author of *Natural History*. Buffon, it will be recalled, had advanced a theory then current in scientific circles that animals on the North American continent were degenerating in size. And he had gone to considerable length to prove that those animals that had been domesticated in both continents had degenerated in America. He attributed the cause incor-

rectly, to the theory that the climate over here was colder and more moist than in Europe. Warmth and dryness, he argued, were more favorable to large quadrupeds.

Jefferson mulled over these theories for some time, and finally came to an exactly opposite conclusion. First of all, he knew the animals of North America. Buffon, he insisted, lacked sufficient climatological, geological, or meteorological data to justify his findings. Jefferson then set about collecting data of his own. By personal investigation and wide correspondence he assembled an immense amount of material. He arranged his data in three tables showing the weights of the animals, so as to give a comparative view.

In his first table Jefferson showed that of twenty-six quadrupeds common to both Europe and America, seven were of equal size. The second table showed that eighteen quadrupeds were peculiar to Europe and seventy-four to America, while one of the seventy-four, the tapir weighed more than all the eighteen together. In the third table the conclusion was reached that with equal care and food the domestic animals of America would reach a growth as great as those of the European stock from which they were derived.<sup>3</sup>

Busy as he was with his *Notes on Virginia* and other activities during the years 1781-1782, Jefferson also found time to take on another scientific, technical study. In January, 1782, the Continental Congress turned to the troublesome question of adopting a standardized monetary system. Robert Morris, financial wizard, brought in a table of the different currencies and exchange rates of foreign coins, and urged the adoption of a fixed standard of value and a money unit. It was a terribly complicated system. Congress postponed action on it until 1784. Jefferson was now a member of Congress and chairman of the commit-

<sup>2</sup> Lipsecomb, XIX, iv-v.

<sup>3</sup> Lipsecomb, II, 66-68.

tee on coinage. He found the Morris plan sound, but "too minute for ordinary use, and too laborious for computation, either by hand or in figures." He pointed out that—

the price of a loaf of bread,  $1/26$  of a dollar, would be 72 units, a pound of butter,  $1/5$  of a dollar, 288 units. A horse or bullock, of 80 dollars value would require a notation of six figures, to wit, 115,200; and the public debt, suppose of 80 millions, would require 12 figures, to wit, 115,200,000,000 units. Such a system of money arithmetic would be entirely unmanageable for the common purposes of society.<sup>4</sup>

Jefferson offered a substitute plan. He would make the dollar the unit of payment, and its divisions would be on a decimal ratio. Jefferson distributed printed copies of his plan to members of Congress, pointing out that the ease with which multiplication and division could be made by using the ratio ten, and the decimal. The advantages of his system were obvious. He also proposed the minting of four coins. First, a gold piece equal in value to ten dollars. Second, the dollar unit itself in silver. Third, the tenth of a dollar, of silver. Fourth, the hundredth part of a dollar, of copper. This system of decimal coinage was adopted both by the Continental Congress and later the Federal Congress, and has remained the basic system to this day.

#### SECOND PERIOD, 1784-1789 Scientific Activities in Europe

In the summer of 1784 Jefferson sailed for France to assist Franklin in negotiating some treaties of commerce and trade. When Franklin retired from his diplomatic post the following year, Jefferson was named his successor. The years he spent in France 1784 to 1789, were busy years, but in some respects this was the most pleasant period of his official life. He found time to carry on many scientific investigations. The French accepted him from the very first as a scientist.

<sup>4</sup> Rayner, B. L. *Sketches of the Life, Writings and Opinions of Thomas Jefferson*, 230.

The two scientific projects in which Jefferson was most interested while abroad were agriculture and natural history. Agriculture came first. Shortly after he reached Paris he was informed of his election to membership in the South Carolina Agricultural Society. In his letter of acknowledgment he sent back some seeds of grass (Malta grass) that had been found especially useful in Malta and in southern France. Later, he sent a collection of acorns from the cork oak, and asked his friends to try them in the South Carolina soil. Jefferson was particularly anxious to introduce the olive culture into the southern states. He sent over several varieties of olive trees and the South Carolina Society accepted them with great enthusiasm, but for some reason they never had much success in developing them.

Jefferson was also interested in rice culture. He was anxious to discover the best methods used in cleaning rice. He traveled down through southern France in 1787 and examined every rice cleaning machine he could find. He also inquired about the methods used by the Italians. Still not satisfied he crossed into Italy and traveled through the rice country in order to study first hand the rice hulling and cleaning machines. He was surprised to learn that the Italians were using the same machines that were being used in South Carolina. He thereupon concluded that it must be the superior quality of the grain that gave the Italian rice supremacy over South Carolina rice.

He decided to send some Italian rice to his Charleston friends, but to his surprise, he discovered that the exportation of Italian rice was prohibited. He then resorted to the ingenious scheme of filling his coat pockets full of rice. At his rooming house he wrapped the seeds in two separate packages and sent them in different ships to Charleston. Both packages reached their destination. These precious grains were distributed to the rice planters of Charleston, and within

a few years, says Curtis, they were producing the best rice in the world.<sup>5</sup>

Later Jefferson sent over samples of an improved rice mill, showing the latest advances in setting the rows of teeth for cleaning the grains. When he discovered an improved quality of corn in Italy, he sent some sample grains to his overseer in Virginia with instructions on how to grow it. In Turin he discovered an improved method for training grape vines. At Casino, France, Jefferson saw an improved rice beater, and spent hours examining it in minute detail.

During the years 1787-1788 Jefferson was busy drafting trade treaties, writing philosophical essays and observing the beginnings of the French Revolution. Yet, he found time to design an improved mold board for plows. He sketched a plan according to a mathematical formula, making the mold board as wide as the furrow, and of a length suited to the construction of the plow. The object was to "secure the regular inversion of a certain depth of the surface soil with the least application of force." For his invention Jefferson was awarded a medal by the Royal Agricultural Society of the Seine.

While on a visit to Holland in the spring of 1788, Jefferson was attracted by a number of their new mechanical contrivances. A saw mill run by wind-power caught his attention, and he made detailed drawings of the mill and all of its parts. While in Germany he made a detailed drawing of a new bridge over the Rhine, and entered a lengthy description of it in his diary. He observed that it was supported by thirty-nine small boats, and described the way they were maneuvered in order to let vessels pass through.

In May, 1788, Jefferson wrote to James Madison, informing him that he was sending a pedometer, and gave him explicit instructions as to its use. It was

<sup>5</sup> Curtis, William Elery, *The True Thomas Jefferson*, Philadelphia (1901) 365.

to be carried in the watch pocket of the vest, and attached by tape to the knee band of the breeches. It must have been an exceedingly delicate instrument, since Jefferson cautioned Madison to never turn the hands backward. He should always note where the hands stood when he began to walk, and determine the number of steps by subtracting that number from the number recorded later.<sup>6</sup>

Jefferson was also interested in the new development of steam power, and kept his American friends informed of the advances that were being made in Europe. On October 2, 1785, he wrote Madison describing a steam engine he had seen in Paris used for raising water for fire protection. The following April he was in London, and after studying the application of steam power used for operating a grist mill, he wrote to his friend Charles Thompson describing it in detail. He foresaw the day when this new source of water would be widely acclaimed in America.<sup>7</sup>

The new advances in printing had a special interest for Jefferson. Perhaps because he did so much writing in long hand he welcomed any short cuts that might be invented. In a letter to Mr. Carmichael, December 26, 1786, he told him he was sending him a portable copying press, model of one that he had recently designed. This polygraph, as he called it, was an ingenious double writing desk with duplicate tables, pens, and inkstands. The pens were connected together by a system of parallelograms, with two fixed centers, so that the pens were always parallel. Whatever movement was impressed on one who was simultaneously communicated by the connecting link to the other pen. By this polygraph the copy was made on another paper identical with the original.<sup>8</sup>

During his entire stay in France Jefferson was diligent in studying all the

<sup>6</sup> Lipscomb, VI, 460.

<sup>7</sup> *Ibid.*, V, 295-296.

<sup>8</sup> *Ibid.*, VI, 31.

recent advances in the arts and sciences. In his letters to President Stiles of William and Mary; to the president of Harvard; to Charles Thompson; to David Rittenhouse and others he gave detailed reports of the many inventions he had seen. The advances made by the French in science, painting, and music, he declared were the only things for which he envied the people of that nation. In writing to Peter Carr in 1785, he declared, "The acquisition of science is a pleasing employment. I can assure you that the possession of it is, what (next to an honest heart) will above all things render you dear to your friends, and give you fame and promotion in your own country."<sup>9</sup>

Two other sciences to which Jefferson gave considerable attention while in Europe were chemistry and astronomy. He was offended when he learned that Buffon, his natural antagonist had made a disparaging remark about chemistry, describing it as nothing more than cookery, and placed the laboratory worker on a footing with that of the kitchen. Jefferson on the other hand, looked upon chemistry as the most useful of all sciences, and one that would open unlimited opportunities for the human race.

Jefferson had a genuine interest in music, both as an artist and a scientist, and while in Europe he found time to keep up his musical interests. In a letter to Mr. Hopkinson, January 3, 1786, he described a new metronome recently invented by Monsieur Renaudin of Paris. Jefferson had recently examined this instrument, and offered suggestions for making some improvements on it.

It will be the greatest present which has been made to the musical world this century, not excepting the piano-forte. Its tone approaches that given by the finger as nearly only as the harpsicord does that of the harp. It will be very valuable.<sup>10</sup>

Jefferson sailed for home late in 1789.

<sup>9</sup> Washington, H. A. Writings of Thomas Jefferson, 9 volumes, (1859). Vol. I, 395.

<sup>10</sup> Lipscomb, VI, 22.

### THIRD PERIOD, 1790-1801

#### As Secretary of State and Vice President

While Jefferson was still in France, President Washington invited him to take over the office as Secretary of State. Jefferson accepted and sailed for America. Busy as he was with the duties of that new office, he found time to continue his scientific interests. One of his first official tasks was to prepare an exact, workable system of weights and measures. He had already given this subject considerable study, but he now desired the opinion of several of his European friends, on this matter. He made a careful study of the system of weights and measures recently introduced in the National Assembly in France. He asked a friend in London to send him a packet of newspapers containing an account of the plan recently submitted by Sir John Riggs Miller to Parliament on this subject. Miller had proposed that a pendulum, 39.107 inches in length be adopted as the standard of measure. The French had also suggested the pendulum as a standard of measure—but recommended it should be 39.181 inches in length. Jefferson took an average of the two, 39.149 inches, and after comparing his results with Sir Isaac Newton's estimate of 39.144 inches, he made his proposal to the House of Representatives in 1790. This document is a classic in scientific literature. But Jefferson was ahead of his time. It was left to another early scientifically minded statesman, John Quincy Adams, to finally secure the adoption of laws regulating the standard of weights and measures in 1838.

Jefferson's most important service to science during his term as secretary of state was the work he did in administering the nation's first patent law. The patent act of 1790 was short, simple and easy to follow. Anything could be patented if it could be classified as "any useful art, manufacture, engine, or device, or any improvement thereon not

before known." It was fortunate that Jefferson, as secretary of state, was charged with the responsibility of administering this law. He was the best qualified person in the nation for this position. Projects of a technical, scientific nature appealed to him. He was constantly encouraging the introduction of new devices and the application of science to every-day living.

The patent law under Jefferson's administration began to function immediately. Within two months after the act had been signed Jefferson wrote that the granting of patents for new discoveries had stimulated inventions "beyond my conception." Jefferson insisted on examining personally every application that was filed. While some of these proved to be useless, "indeed trifling," as he said, yet there were many of such consequence that they would produce great results.

While serving as secretary of state, Jefferson was appointed chairman of a committee in 1792 by the American Philosophical Society to collect information relating to the ravages of the Hessian fly. This insect was threatening to destroy the wheat crop and other grain crops of the country. Jefferson's work in assembling all available data on this pest was the first organized effort in economic entomology in the United States.

In December, 1793, Jefferson resigned as secretary of state and returned to his home at Monticello. During the next three years he devoted considerable time to agriculture. His experiments in crop rotation, which required a six year cycle for completion, attracted considerable attention. He also carried on experiments with an improved plow. Writing to John Taylor of Caroline, December 29, 1794, he declared that "a good instrument of this kind (referring to his plow) is almost the greatest desideratum in husbandry."<sup>11</sup>

<sup>11</sup> Lipscomb, XVIII, 199-200.

During these same years he was experimenting with a drill, called "the Carolina Drill" which was operated for only one row at a time. He wrote to President Washington, June 19, 1796, saying that he was trying to improve the drill so as to make it sow four rows of wheat or peas at 12 inches distances. And in the same letter he described a Scotch threshing machine which he had nearly finished. He had worked from a model which Mr. Pinckney had sent him. He had succeeded in putting the whole works, except the Horne wheel, into a single frame, so that it could be moved from one field to another on two axles of a wagon.<sup>12</sup>

In 1796 Jefferson was elected vice president of the United States. When he left Monticello to go to Philadelphia for the inauguration, he carried with him an extensive collection of newly discovered bones, and an elaborate set of notes describing the studies he had made of them. What a spectacle! A statesman renowned in two continents, elected to the second highest office in the land, entering the nation's temporary capitol, bearing a collection of bones that would claim almost as much attention as any of the affairs of state! The week following his inauguration as vice president, Jefferson read a paper before the American Philosophical Society entitled, "Memoirs on the Discovery of a Quadruped in the Western Parts of Virginia." He called the animal, bones of which he had recently discovered, *The Meglonyx Jeffersoni*. The science of paleontology had its beginnings, as nearly as any science can have a beginning, with Jefferson's paper on *Meglonyx Jeffersoni*. He was immediately elected president of the Philosophical Society and served until old age compelled him to resign in 1814.

Jefferson was an ardent believer in developing the scientific possibilities of

<sup>12</sup> Randolph. Writings of Thomas Jefferson, III, 338.

this young nation. In a letter to Elbridge Gerry in 1799, he wrote:

I am for encouraging the progress of science in all its branches; and not for raising a hue and cry against the sacred name of philosophy; for awing the human mind by stories of raw head and bloody bones to a distrust of its own vision, and to repose implicitly on that of others; to go backward instead of forward, to look for improvement; to believe that government, religion, morality, and every other science were in the highest perfection in the ages of darkest ignorance and that nothing can ever be devised more perfect than what was established by our forefathers.<sup>13</sup>

The sciences which he believed most useful and practicable were botany, chemistry, zoology, anatomy, surgery, medicine, natural philosophy, agriculture, mathematics, astronomy, geography, politics, commerce, history, ethics, law, and the fine arts.

#### FOURTH PERIOD, 1801-1809 President of the United States

During the exciting weeks in February 1801, while Congress was busy trying to break the tie vote between Jefferson and Burr, Jefferson was engaged in correspondence with Dr. Caspar Wistar discoursing on some bones of a mammoth that had recently been dug up in Ulster County, New York. Pressing as were the matters of state they did not claim his undivided attention.

Within less than three weeks after he had been inaugurated president, Jefferson was writing to Moses Robinson, United States Senator from Vermont, expressing the hope that the people of America, in all professions, would see the necessity for scientific advancement. He pleaded for an open minded attitude in all scientific matters. He was especially anxious to have the members of the clergy recognize the advances in sciences.

I am in hopes their good cause will dictate to them, (the clergy) that since the mountain will

<sup>13</sup> Ford, P. L. *Writings of Jefferson*, VII, 328.

not come to them, they had better go to the mountain; that they will find their interest in acquiescing in the liberty and science of their country, and that the Christian religion, when divested of the rags in which they have enveloped it, and brought to the original purity and simplicity of its benevolent institutor, is a religion of all others most friendly to liberty, science, and the freest expansion of the human mind.<sup>14</sup>

During his eight years as president, Jefferson continued to give such time as he could spare to matters of scientific interest. But matters of state did not permit as much study or correspondence as in former years. The most dramatic scientific event of his first term, carried over into his second, was of course, his decision to send Lewis and Clark on that scientific expedition into the far northwest.

From 1801 to 1807, aside from the Lewis and Clark expedition, only a few letters can be found bearing specifically upon scientific subjects. But as he approached the end of his second term an increased interest is noted. On January 3, 1808, he wrote to Robert Livingston in Paris, thanking him for sending over the copies of the *Agricultural Proceedings*. He expressed surprise to learn that the system of crop rotation was just coming into common use in France.<sup>15</sup>

To John Taylor of Caroline, January 6, 1808, he described an improved grain drill that he had especially made for his fields. He planned to send one over to the Agricultural Society of Paris. He had recently received an improved plow from the Paris Society, which according to the French inventor claimed to be the best plow ever built—one that required only two thirds the force ordinarily used to pull other plows.<sup>16</sup>

Jefferson was eagerly looking forward to his retirement. In a letter dated July 15, 1808, to Monsieur Lasteyrie, he said:

When retired to rural occupation, as I shall be ere long, I shall devote myself to occupations

<sup>14</sup> Randolph, III, 471.

<sup>15</sup> Lipsecomb, XI, 411.

<sup>16</sup> *Ibid.*, XI, 414.

much more congenial with my inclinations than those to which I have been called by the character of the times into which my lot was cast. . . . What remains to me of physical activity will chiefly be employed in the amusements of agriculture.<sup>17</sup>

It was with genuine relief that on March 4, 1809, Jefferson retired from "the dry and dreary waste of polities."

#### FIFTH PERIOD, 1809-1826

##### In Retirement—The Sage of Monticello

Jefferson retired from "the dry and dreary waste of polities" March 4, 1809, and returned to that place which he loved "more than all the kingdoms of earth." The "Sage of Monticello" would have preferred to become the "Hermit of Monticello," but his fame as statesman, diplomat, and scientist, would not permit. During his first year in retirement he spent considerable time constructing a plow, fitted out with his special mold board, for the Agricultural Society of the Seine. He believed less power would be required to pull his plow than the plow which the Society had sent him. But in this, as in all of his other scientific theories, he wrote Robert Fulton, "it is the actual experiment alone which can decide."<sup>18</sup>

In April, 1913, he wrote Charles W. Peale, prescribing a scientific method of plowing hilly ground, known today as contour plowing. The furrows, he said, should be plowed along the side of the hill, horizontally and in parallel lines. This could be accomplished by means of a triangular level, whereby points for guide furrows were marked out on the hillside, at distances of about thirty to forty yards apart. From these guide furrows the intervening furrows could be determined.<sup>19</sup> This plan was apparently Jefferson's own, and again it reveals his extreme meticulousness in planning his scientific projects—in this case,

even to the uniformity of distances between furrows on the hillsides of his farm.

During his years in retirement Jefferson was busy with many other inventions. He designed an improved hemp break, which powered by a single horse would do "the breaking and beating of ten men," a new threshing machine, an adjustable book case, a whirling chair (the modern swivel chair), a folding chair, a carding machine, and a lock dock for laying up vessels.

Jefferson was a strong advocate of applied science. In March, 1818, he wrote to Benjamin Waterhouse, declaring:

When I contemplate the immense advances in science and discoveries in the arts which have been made within the period of my life, I look forward with confidence to equal advances by the present generation, and have no doubt they will consequently be as much wiser than we have been as we than our fathers were, and they than the burners of witches.<sup>20</sup>

In some respects Jefferson belonged to the twentieth century rather than the late eighteenth or early nineteenth. He had very definite views on the relations between science and government. As he looked back over a half century of active participation in political life, he wrote in 1821 that:

Science is more important in a Republic than in any other government. And in an infant country like ours, we must much depend for improvement on the science of other countries, longer established, possessing better means, and more advanced than we are. To prohibit us from the benefit of foreign light, is to consign us to long darkness. . . . Science is important to the preservation of our Republican government and it is also essential to its protection against foreign powers.<sup>21</sup>

Jefferson died on July 4, 1826. Thus ended the career of our first statesman-scientist. His scientific interests comprised an important part of his whole thought and definitely shaped his entire philosophy of life.

<sup>17</sup> *Ibid.*, 92.

<sup>18</sup> Lipscomb, XIX, 173.

<sup>19</sup> Lipscomb, XVIII, 279.

<sup>20</sup> Lipscomb, XV, 87, 165-166.

<sup>21</sup> Washington, ed. VII, 221.

## DID THE FOLSOM BISON SURVIVE IN CANADA?

By Dr. LOREN C. EISELEY

ASSOCIATE PROFESSOR OF ANTHROPOLOGY, UNIVERSITY OF KANSAS

### I

IN 1927 a wave of incredulous surprise swept the archeological world. The discovery, at Folsom, New Mexico, of the bones of a supposedly extinct Ice Age bison in association with implements of human manufacture, shook to its foundations the theory of conservative archeologists that man had been a late arrival in America. Instead, a series of discoveries scattered over the High Plains region of the United States has revealed that man reached the American continent in time to see the last of the giant mammals of the Ice Age—the mammoth, the huge and lumbering sloths and the now extinct American horses and camels. All this is now archeological history. The specialist no longer scoffs as the earth continues to yield up evidence of these thinly scattered mammoth hunters remotely ancestral to the American Indians of to-day. The sole question not entirely answered to the archeologist's satisfaction, as yet, is the exact date at which the last of these extinct animals disappeared. And since these early people hunted the huge buffalo of the time with marked success, particular interest has lingered about these long-horned relatives of our familiar American bison of to-day.

The American bisons of the late Ice Age are known primarily from skulls and various fragments of the body skeleton recovered over a wide range of territory in the United States. That they averaged somewhat larger in size than the existing buffalo is well known. Differences in horn and skull structure among different types have resulted in at

least the tentative setting up of several distinct species, some of which were apparently in existence at the same time. Some of these types undoubtedly constitute valid species. In the case of others, however, different observers may have been too liberal in the description of new species on the basis of inadequate material which, at best, may have represented only local varieties or races. It is possible also that certain of these co-existing types may have mixed or interbred, thus increasing the problem of systematic assignment. Furthermore, sex differences may have played a part in confusing the paleontologist. No really authoritative and complete study of these bison, in spite of their growing importance to the archeologist, has been made in recent years.

The common tendency of late has been to term most of the bison recovered with Folsom or Yuma archeological remains as *Bison taylori*. As so used, however, it must be remembered that the appellation *taylori* probably includes animals which some years before the Folsom controversy would have been termed *Bison antiquus* or *Bison occidentalis*. *Bison taylori* was described by Hay and Cook from the original Folsom quarry at Folsom, New Mexico. There is no doubt that it was somewhat larger and more powerfully horned than the existing American bison. It was, however, closely related to the latter form which succeeds it at some undetermined point within either very late glacial or early Recent time. In other words, at a point in years anywhere from perhaps 15,000 to 8,000 years ago.

It is quite likely that these big animals were adjusted to cooler Ice Age conditions and failed to hold their range with the onset of postglacial warmth and drouth. The existing bison may have been a successful southern variant of this stock. Adjusted to enduring a dryer and hotter prairie environment, it may have flooded in over the range once held by the larger and more formidable species.

*Bison taylori* in this case may have survived longer toward the north where he could have intruded into areas once covered by the great ice-sheets. Because of inadequate investigation of the vast Canadian wilderness, our information here is almost entirely speculative at present. The story which we have presented so far is one whose essential outlines are accepted by all archeologists at least in so far as it concerns discoveries within the United States. It is within this northward area, then, that a certain degree of mystery presents itself—a mystery which has seemingly escaped the eye of those very students who have been struck by man's association with an extinct ice-age animal in the High Plains region of the United States.

## II

When the first voyageurs explored the wilderness of the Canadian Northwest they found bison ranging over most of the upper part of the Mackenzie Basin. As time passed and the acquaintance of the white man with the North American game animals increased, many hunters began to express the view that the northern Canadian bison were somewhat distinct in size, pelage and habits from their relatives, the Plains bison. On the whole they were regarded as a larger and more rugged variety of the southern form. An early quotation from Sir John Richardson (*Fauna Boreali-Americana* 1829) will illustrate the trend in the literature:

The bison which frequent the woody parts of the country [near Great Slave Lake] form smaller herds than those which roam over the plains, but are said to be individually of greater size.

Finally, in 1897, the paleontologist, S. N. Rhoads, clearly defined the wood bison as a subspecies (*Bison bison athabascae*) of the better known Plains bison (*Bison bison*), and supplied its scientific description.<sup>1</sup> Since that time there has been little attempt to challenge the form as a valid variety of *Bison bison*.

Some of the early descriptions of these big animals, though lacking metrical expression, are not without interest and may well serve to introduce the features which will later demand our attention with reference to the paleontological past. Though variations and misstatements exist in the descriptions, there is considerable emphasis, particularly in the earlier accounts, upon large size and greater length of horn "nearly twice the length of the plains' ones and much straighter."<sup>2</sup>

The naturalist, Ernest Thompson Seton, in 1914, describing a large bull which he was able to examine in Canada, speaks of the "immense horns long and curved," of the "enormous bulk, evidently larger than any Plains buffalo and much like an aurochs."<sup>3</sup>

When Rhoads in 1897 gave his description of the type, he pointed out that "In *athabascae* the relative length of the horns and horncores to the size of the skull is about the same or even greater than in *antiquus*. . ." Though endeavoring to establish distinctions,

<sup>1</sup> S. N. Rhoads, "Notes on Living and Extinct Species of North American Bovidae," *Proceedings of the Academy of Natural Sciences of Philadelphia*, Vol. 49, pp. 492-500, 1897.

<sup>2</sup> *Ibid.*, p. 497, quoting H. I. Moberly. Also see C. Gordon Hewitt, "The Conservation of the Wild-Life of Canada," p. 124. Scribners, New York, 1921.

<sup>3</sup> E. T. Seton, "Lives of Game Animals," Doubleday Doran, N. Y. 1929. Vol. III, Pt. 2, p. 707.

Rhoads concludes that "the weight of evidence favors their position between *B. bison* and the most recent fossil species."<sup>4</sup> *Bison antiquus*, of course, is one of those types of late Pleistocene bison suspected of association with early man in America. In fact, in the eyes of some paleontologists, *Bison taylori*, the bison found at Folsom, New Mexico, is really only a varietal form of *antiquus*.<sup>5</sup>

In spite of these tantalizing statements, which could easily be multiplied by scanning the literature, a marked confusion seems destined at the present time to obscure forever the true affinities of the northern bison. The tragedy happened in the following manner: The northern bison, just as in the case of their Plains' relatives, became steadily reduced in numbers throughout the nineteenth century. At one time in the eighteen eighties or nineties, they were definitely threatened with complete extinction. Just how close they came to disappearance is not known,<sup>6</sup> though estimates have ranged as low as fifty head.<sup>7</sup> In 1893 the first laws were passed to protect the animals and, though inadequately enforced, they served to relieve the situation. A small upswing in numbers took place during the following years.

In 1925, however, the Canadian government carried out a policy which, though well intentioned in terms of game conservation, has served to make a complete investigation of the original character of *B. bison athabascae* exceedingly

<sup>4</sup> Rhoads, *op. cit.*, p. 500.

<sup>5</sup> E. H. Barbour and C. Bertrand Schultz, "Paleontologic and Geologic Consideration of Early Man In Nebraska," *Bulletin Nebraska State Museum*, Vol. 1, pp. 434-435, 1926.

<sup>6</sup> H. M. Raup, "Range Conditions In the Wood Buffalo Park of Western Canada with Notes on the History of the Wood Bison," *Special Publication of the American Committee for International Wild-Life Protection*, Vol. 1, No. 2, p. 5, 1933.

<sup>7</sup> J. A. Allen, *Bulletin American Museum of Natural History*, Vol. 13, p. 67, 1900.

difficult. Large shipments of Plains bison were introduced into Wood Buffalo Park, a tract of land in Northern Alberta roamed over by the last of the northern bison.<sup>8</sup> Hence, at the present time, the two varieties are inextricably intermingled. One of the tragedies of this situation lies in the fact that save for a few measurements on the type skull as given by Rhoads, no authentic measurements exist in print. It is true that a few measurements have been given of skulls collected since the introduction of the Plains bison into the Wood Buffalo preserve, but it is obvious in these instances that the strain represented is uncertain.<sup>9</sup> Moreover, they were collected before the archeological and paleontological problem which we are approaching had become significant enough to center attention upon what was needed in the way of information.

### III

Now what has this remote bison remnant to do with the archeological past in which we are interested? Primarily this. In the first place, no attention has been given in archeological or paleontological literature to the position and range of this variety of bison during the maximum southward stand of the Wisconsin ice which represents the last glacial advance of the closing Pleistocene or Ice Age. If *Bison bison athabascae* existed during this period its range may well have projected downward into the

<sup>8</sup> A formal protest was made by the American Society of Mammalogists. Prophetically, the protest reads in part as follows: "Interbreeding would take place between the races of Plains Buffalo and Wood Buffalo, so that the distinctive characteristics of the Wood Buffalo would be lost in a few generations, and in this way the largest and noblest game animal of North America would pass out of existence as such." A. B. Howell, *Canadian Field Naturalist*, Vol. 39, p. 118, 1925.

<sup>9</sup> Raup, *op. cit.*, p. 19, 33. Also J. Dewey Soper, *Journal of Mammalogy*, 23: 144, 1942.

United States because its historic range would have been largely ice-covered.

Under these circumstances, there is a very genuine possibility that its bones might appear in the western deposits where the traces of early man in America are now in the process of discovery. Because of its size, irrespective of whether we regard it as directly related to the extinct form *Bison taylori*, limb fragments of this bison might easily be attributed to the extinct form. From this standpoint alone the animal deserves more attention than it has yet received in the literature.

The writer has repeatedly emphasized that where identifiable skull fragments are lacking, as is often the case in cave deposits and sand "blow out" sites in the West, limb or other fragments may be the only means of establishing the presence of bison. If these fragments are associated with Folsom or Yuma points, there has been a strong tendency to assume automatically—particularly if the size of the limb bones is reasonably large—that the bison represented is the same type known from Folsom, New Mexico, or the Lindenmeier site at Fort Collins, Colorado. Now most certainly there is every reason for regarding this as a reasonable assumption. Nevertheless, so long as the skull is missing, *absolute, positive identification is impossible*. The fragments of the body skeleton of the late Pleistocene bison overlap in measurements upon the normal range of *Bison bison*, and do not differ enough morphologically that they can be separated, at least so far as present knowledge goes, on the basis of non-metric characters.

Allen recognized this fact many years ago when he wrote:

The female of the larger extinct species, judging from the sexual differences seen in the living species, would apparently about equal in size the male of the smaller one, and hence it is difficult to positively, specifically assign such specimens

as detached teeth or single bones of the extremities.<sup>10</sup>

Only where sufficient long bones are present to derive data capable of statistical manipulation might something be done on the basis of metrics alone. Yet even here the necessary comparative data have not been adequately compiled. Statistical developments in paleontology with the notable exception of the work of Simpson<sup>11</sup> and a few others have lagged. The zoologist Richards stated no less than the simple truth when he said, "Taxonomic description of species is usually insufficiently quantitative. . . . Even where linear measurements are given they are not usually recorded in a form suitable for analysis. Standard deviations are rarely calculated even where averages are recorded."<sup>12</sup>

In the light of these technical difficulties which we have just reviewed, it would appear that there exists a reasonable possibility that *Bison bison athabascae* represented, at least in a mixed form, the last of that Ice Age bison which early man had hunted in the western plains. If that bison as represented by the form or varieties variously designated as *taylori*, *antiquus* or *occidentalis* was adjusted to cooler and more forested conditions, it may, under the rising temperature following the ice-retract, have moved along the fringe of the receding ice toward the north. At the same time its near relative or actual mutant, the existing Plains bison, may have infiltrated into its former range. This latter animal, doubtless better adjusted to postglacial warmth and dry

<sup>10</sup> J. A. Allen, "The American Bisons: Living and Extinct," *Memoirs of the Museum of Comparative Zoology*, Harvard University, Cambridge, Mass., p. v, 1876.

<sup>11</sup> G. G. Simpson, *American Journal of Science*, 239: 785-804, 1941.

<sup>12</sup> O. W. Richards, "The Formation of Species," in G. R. de Beer, "Evolution: Essays on Aspects of Evolutionary Biology," Oxford Press, 1938, p. 96.

prairie conditions, continued to flourish into historic time. The big Woodland bison, perhaps originally representing the *taylori* type, mixed and intergraded somewhat with the Plains bison in the northern areas. It suffered a brief period of isolation when the southern bison were exterminated and then, due to the renewed introduction of numbers of Plains bison, was tremendously diluted as a type. This dilution is not likely to have been entirely a product of late mixture, unfortunate though the latter has proved. In the days of the great herds it is not likely that there was a complete dichotomy between two such closely related forms.

The few measurements given by Rhoads of a specimen collected before the 1925 introduction of Plains bison into the preserve, fall within the range of measurements recorded for individual fossil remains of specimens of *taylori* and *occidentalis* here in the United States. Unfortunately no extended series of measurements of early specimens exist, and no early skulls are figured. Most of the few records available are of the living body and are not directly comparable to the osteological measurements of the paleontologist. Mystery clothes both the disappearance of the big bison hunted by Folsom Man and the shadowy northern form whose description, at least in some instances, sounds suspiciously similar. Because of the undoubtedly intermingling, however, both early and late, the situation is not one which promises easy clarification.

Nor must the thesis of this paper be taken opportunely as justification for dismissing the antiquity of the Folsom and related cultures. Folsom Man knew other extinct Pleistocene beasts besides *Bison taylori*. In addition, even if we

had final and decisive proof of the relationship of *taylori* to *Bison bison athabascae*, or could show the actual survival of the former in the northern woodland within recent centuries, we would not have altered the possible antiquity of Folsom Man. Rather, by relating the shifting bison ranges to the glacial events of the terminal Pleistocene we may profitably consider whether so marked a modification of the type of bison within the High Plains area of the United States can be reasonably divorced from a direct relationship to the climatic changes of that period. It is by no means without interest that the only documented discovery of both *Bison bison* and *Bison occidentalis* in a deposit which may represent the contemporaneous existence of both forms is from a peat bog in Minnesota surmounting Wisconsin drift.<sup>13</sup> Here, perhaps, is the big glacial form fading northward and here is *Bison bison* coming in. Interestingly enough, one or two of what seem to be the most recent survivals of the late Pleistocene bison have been reported from Canadian areas.<sup>14</sup>

Only more extended exploration of the Canadian wilderness and the intensive comparison of its fossil bison will illuminate the whole problem. Until that time, however, a question must exist as to whether the "extinct" Folsom bison lingered on into historic time, at least as an attenuated and mixed remnant on the northern fringe of that great continental bison range which the early travelers described as "making the earth one robe."

<sup>13</sup> Frank Leverett, "Quaternary Geology of Minnesota and Parts of Adjacent States," U.S.G.S. Professional Paper No. 161, p. 144, Washington, 1932.

<sup>14</sup> O. P. Hay, "The Pleistocene of the Middle Region of North America and Its Vertebrate Animals," Carnegie Publication No. 322A, Washington, 1924, p. 200.

## BOOKS ON SCIENCE FOR LAYMEN

### MAN'S POOR RELATIONS<sup>1</sup>

MAN'S "poor relations" are the apes, monkeys and lemurs which, together with man, constitute the mammalian order of Primates. The technical literature appertaining to primates has grown to respectable size especially during the last few decades (see T. C. Ruch, *Bibliographia Primateologica*, 1941), but no one up to now had ventured to make use of this literature for producing a book in English which brings together in a single volume all the available information on man's nearest animal relations. We do possess comprehensive technical monographs on the taxonomy of primates (notably D. G. Elliot, *Review of the Primates*, 3 vols., 1913), on the general natural history and psychology of the man-like apes (especially R. M. Yerkes and A. W. Yerkes, *The Great Apes*, 1929), on the brain of primates (*e.g.*, F. Tilney, *The Brain from Ape to Man*, 2 vols., 1928), and many other splendid works, but these are always limited in scope to one or a few of the many different specialties. In the volume under review the educated layman is finally told, based upon authoritative sources, what his numerous cousins look like, where and how they live, what and how they eat, why and how they fight, how and when they love, how they are constructed, what their ancestors were like, which among the many resemble man most closely, and a great deal more besides. All these varied data are of greatest help for a full understanding of human nature since all primates, including man, are the results of more or less diverging evolutionary experiments derived from one, long ago extinct, ancestral stock which gradually became changed by widely varying degrees into the six hundred odd different

species of to-day. That man is merely a modified monkey has come to be fully recognized not only by anatomists and physiologists, but also by psychologists and lately even by some sociologists. The long standing lack of a comprehensive popular book on primatology is a reproach to our scientific age which prides itself on sharing its findings with the general public. The average layman of to-day possesses hardly more interest in or knowledge of his simian cousins than did Gilbert and Sullivan who stated some time ago: "Man, however well behaved, at best is but a monkey shaved."

Professor Hooton says of his present book that it "represents an anthropologist's temporary revulsion from the study of his own kind and his resort to a contemplation of other primates which, if they are monkeys, behave in a manner befitting monkeys, and if they are apes, live up to their apehood. They have probably fulfilled their evolutionary aspirations, if they have any. At least they make no pretense of being better and more intelligent than they are. If man insists upon aping the apes, he ought at any rate, to quit posing as an angel." In his introduction the author remarks that: "When you have considered this very general and non-technical summary of man's physical uniqueness, you are likely to conclude that he is just another primate after all and not so god-like in his aberrances as we commonly fancy him to be." It is evident that the author, as all competent students of primates, takes no undue pride in man's achievements, whether of the body or in behavior, and that he is not the least ashamed of his animal kinsfolk.

The first part of the book, and really more than one third of it, is devoted to what are called the "Ape Aristocrats," *i.e.*, that small and select company of man-like apes, the African gorilla and

<sup>1</sup> *Man's Poor Relations*. Earnest Hooton. Illustrated. xl + 412 pp. \$5.00. 1942. Doubleday, Doran and Company.

chimpanzee and the Asiatic orang-utan, siamang and gibbon. These resemble man unquestionably most closely in body and mind and, indeed, are in some respects even more highly developed than is man himself. It is not for this reason alone, however, that so much space has been assigned to these five genera, but it is due also to the fact that as much has been learned concerning these few anthropoid apes as about the remaining fifty odd primate genera together. The second and third parts of the book describe the numerous Old and New World monkeys in considerable detail. This is followed by a section dealing with the lowly prosimians and their varied and localized specializations. The final part of the volume, entitled "Man and His Primate Peers and Inferiors," summarizes the most significant discussions of the preceding chapters and this under the following main headings: Sex and Society; Blood and Relationship; Brains and Behavior; Bones and Body Build; Extinct Ancestors and Collaterals—Mostly Teeth; and finally Evolutionary Prospects.

As an introduction to primatology and as a first attempt to produce a popular and comprehensive textbook on non-human primates this volume is a welcome addition to the libraries of anthropologists and psychologists; indeed, it is to be hoped that it will find a place on the bookshelves of all people aspiring to a real "liberal education." It is very entertainingly written and illustrated generously with excellent and well-selected photographs. That it contains some minor errors and inaccuracies is hardly surprising in a work of this vast scope including many widely differing and often highly specialized fields in each of which only an expert can know all that has become known and discriminate between tentative and well-substantiated results. The comparatively brief references to the anatomy of the soft parts in

the various groups of primates are far from doing justice to the present state of our knowledge concerning these complex problems. In this field considerable progress has been made in recent years, particularly through the work of American investigators, notably Wislocki, Fulton, Straus, and others.

Professor Hooton's latest book fills a great need by stimulating popular interest in primatology and by counteracting the anthropocentricity which is so difficult to eradicate in our thinking. People should become better acquainted with Man's Poor Relations and this can be easily and pleasantly accomplished by reading this frank account of all the other members in man's zoological fraternity—the Primates. It is most appropriate that the volume has been dedicated to Professor Robert M. Yerkes, who, more than anyone else, has enriched our knowledge of the behavior of the man-like apes.

ADOLPH H. SCHULTZ

#### CUCKOOS AND THEIR EGGS<sup>1</sup>

THIS book, based on the author's very large collection of parasitic cuckoos' eggs, mostly from India and Europe, and his long interest in the study of these birds, deals mainly with the problem of the evolution of adaptive similarity between the eggs of the parasites and those of their hosts. Unfortunately the bulk of the material was collected by untrained and even native assistants, with the result that the data are often open to suspicion, while to make the matter still less satisfactory the author seems to feel that his belief in his conclusions can be transmitted to his readers without adequate supporting evidence. This makes the book very disappointing indeed as a result of a lifetime of effort. However, there are some data and some ideas contained in it that are of interest, but it takes a special student of the sub-

<sup>1</sup> *Cuckoo Problems*. E. C. Stuart Baker. Illustrated. xvi + 207 pp. 25/-, 1942. H. F. & G. Witherby, Ltd. (London).

ject to pick out the kernels of grain from the chaff. For the general reader this critical selection is well-nigh impossible, and the only benefit that he may hope to derive from the book is a general picture of what the parasitic habit of the cuckoos is like without getting any satisfying explanation or even clarifying approach to it. On the other hand, it must be said in the author's defense that as experienced a student of adaptation as Poulton (who contributes an appreciative foreword to the book) appears to consider the work important, interesting and valuable as a contribution to evolutionary studies. All the present reviewer can say is that he does not agree.

To state the author's main problem in a few words, the general picture is this: While the individual species of cuckoos victimize many species of birds, the tendency is for each individual hen cuckoo to use nests of but a single species of fosterer; the eggs laid by any one cuckoo are all very similar, although there may be wide variation in the eggs of each species of cuckoo; in a large number of cases there is a general (and in some cases a close) similarity between the eggs of the parasite and those of its host or fosterer.

Baker's approach to this problem is to assume that those cuckoos that show little or no egg similarity to their hosts are more primitive as parasites than those that show more complete egg adaptive similarity. While it is very easy to arrange the material in this way there is no proof that it is the correct one. Furthermore, Baker assumes that parasitism is not a secondarily arrived at condition in the cuckoos (involving an historical loss of the nest-building and egg-incubating instincts) but an original one, right through from some hypothetical reptilian ancestor (!). Aside from the fact that this is so very unlikely as to be dismissed from serious consideration, it implies a contradiction to his argument for the need of adaptive resemblance in

eggs, for the cuckoos that he assumes to be less well developed as parasites have then survived successfully a longer time than those with better developed egg adaptations, and appear to be in no danger of dying out because of their egg "handicaps."

In spite of its very serious shortcomings the book presents some basic data of interest and should be consulted (but with great critical discretion) by a reader intending to study the complex problems involved. The book is compact in its textual matter and quite free from typographical errors and is illustrated by eight colored plates of eggs and four black and white ones of birds and nests. There is no index.

HERBERT FRIEDMANN

#### INTIMATE STUDIES OF INSECTS

"A LOT OF INSECTS"<sup>1</sup> is the wholly inadequate title of the very remarkable new book by Dr. Lutz. Far from being a mere annotated listing of the 1,402 species of insects that he collected on the suburban lot on which he lives with them, it is the repository of the ripe experience of a lifetime devoted to the first-hand study of insects and their ways. The book is a record of personal observations and experiments, which as the brief preface indicates were begun where "the laboratory was sometimes in our cellar, and sometimes in one of the flower beds on the lawn," and were continued wherever the service of the American Museum of Natural History called him.

It is the kind of book that only Dr. Lutz could write. It is the story of his own personal interests in and experiments with insects of many kinds. It is all informing and much of it is very entertaining. Flashes of humor and unexpected turns of thought abound, and much good-natured dealing with controversial questions, and frequent confes-

<sup>1</sup> *A Lot of Insects*. Frank E. Lutz. Illustrated. 304 pp. \$3.00. 1941. G. P. Putnam's Sons.

sions of ignorance, that indicate the highest type of wisdom. He says "Let us not be dogmatic about things of which we are really ignorant."

It will do a lot of people a world of good to read this book.

JAMES G. NEEDHAM

#### KNOW THYSELF<sup>1</sup>

PSYCHOANALYSIS has benefited a great many people who otherwise would have remained crippled and ineffectual in personal and social relations. In view of the great deal of time, money and energy that has to be expended to effect a successful analysis, it appeared to Dr. Horney pertinent to raise the question whether self-analysis was possible. Hardly, however, does she state the question, than immediately comes the answer that such an analysis is at best a matter of considerable doubt; and in this she is entirely right, for the problem is a pseudo-problem. The successful advance of psychoanalysis is perhaps the best argument against self-analysis. The office of the psychoanalyst is filled with patients who have attempted from time to time to effect a cure by self-analysis, not only with negative but often disastrous results, and no patient is more difficult to handle than he or she who has made various attempts at self-analysis. The book, therefore, is devoted to the discussion of the more limited types of self-analysis which are confined to those cases that have at one time or another been or continue to be under the care of the analyst. In this sense, therefore, the title of the book is a misnomer and entirely misleading, for the readers, on the basis of the title of the book, would suppose that the author discusses personal self-analysis without the help of anyone, yet it turns out that the book deals entirely with such types of self-analysis as are only possible under the guidance and the help of the psychoanalyst.

<sup>1</sup> *Self-Analysis*. Karen Horney. 309 pp. \$3.00. 1942. W. W. Norton and Company, Inc.

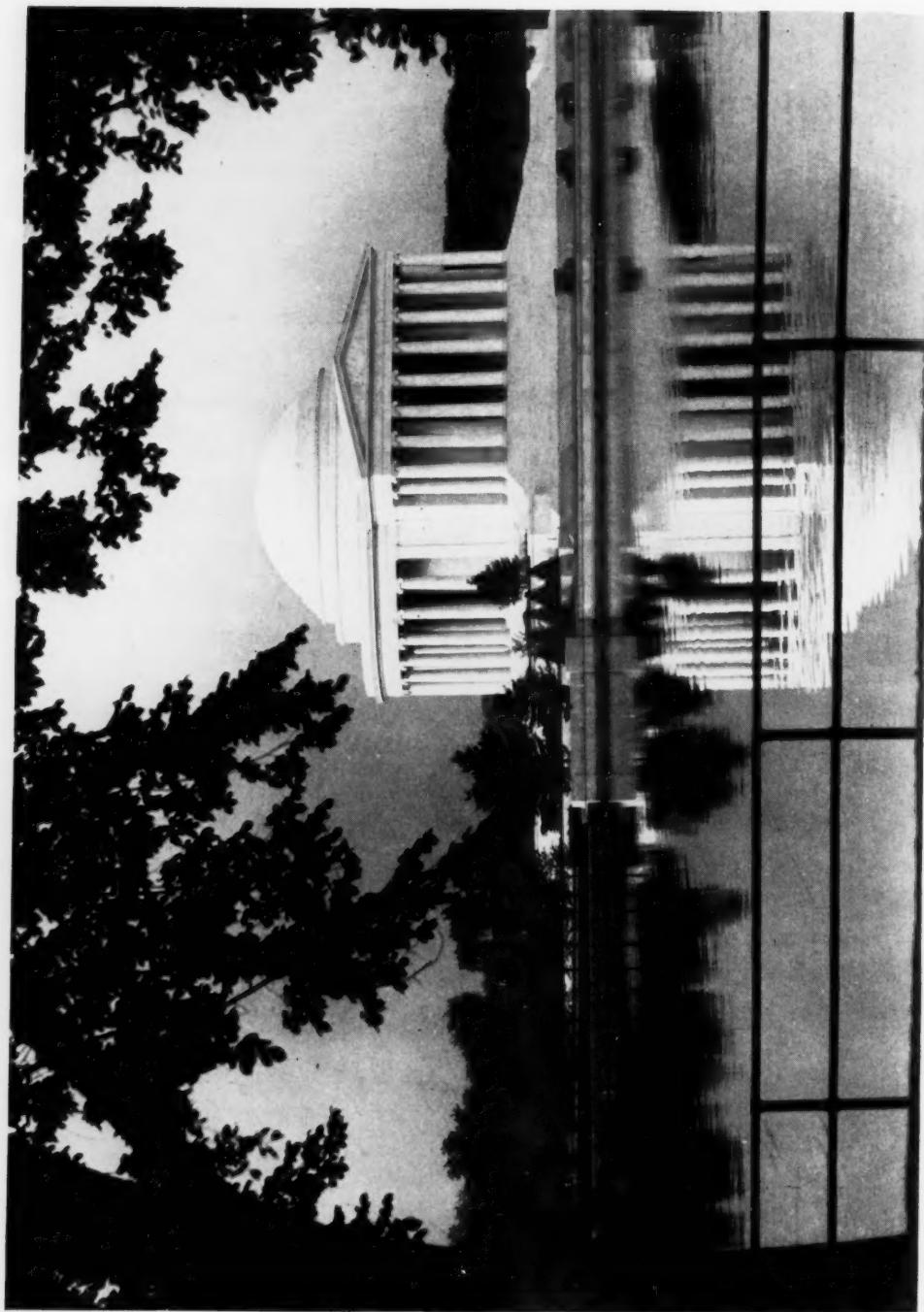
It is not that Dr. Horney herself is unaware of the limitations of self-analysis as given above, for she offers numerous arguments against it, citing, for instance, the case of Rousseau. She could have given a closer instance in this country of Professor William Ellery Leonard, who, in his "The Locomotive God," has made a determined effort to analyze himself. Any one, reading these two books and any others of this type, will have no difficulty seeing that all these strenuous attempts at self-analysis completely fail for the very reason that in such analysis the patient works against his own inner resistances which he is too blind to perceive and, therefore, can not dispose of. It is in order to combat the development of resistance that competent analysts the world over invariably require the patient to dismiss psychoanalysis from his mind except during the actual analytic session. Additionally, in self-analysis, the subject is unable to establish a transference, the need of which is an acknowledged axiom in analysis and the very essence of a psychotherapeutic cure. But we do not have to cite the examples of Rousseau and Professor Leonard. We have a closer instance at hand in the case of Freud himself, who, as the originator of psychoanalysis, has made an exceptionally strong effort to analyze himself. Any one who is at all acquainted with psychoanalysis knows how many things Freud has missed in his own life because he was unable to overcome his own resistances. The discovery by him of the so-called castration complex is found, on unbiased and objective analysis, to be but a rationalization of his own powerful, but unanalyzed masculinity complex. If Freud himself was unsuccessful in self-analysis, what chance does an ordinary mortal have? Again, recognized psychoanalytic organizations, including the one to which Dr. Horney belongs, demand of prospective analysts that they be first analyzed. If this is demanded of normal

physicians, can less be expected of sick laymen?

Apart from these considerations, however, the book would still have some justification were it not written in a novelesque, popular, but very deceptive style. The material presented is not discussed in anything like a scientific manner. The scientifically oriented reader who would expect the cases to be planned, and precisely and systematically organized, will have great difficulty in reading the book. Cases are presented in small bits with many interruptions. Thus, the most fully described case runs along for close to two hundred pages, a little bit here, a little bit there; these bits of history being sandwiched in between other material not directly related to them. The style is deceptive because it reads very easily, but when one gets through reading, it is exceedingly difficult to get hold of the stuff and substance of the book. It is like a vegetarian dinner, which fills you while you are eating, but half an hour later you are hungry again.

The book should never have been written. It adds nothing to our clinical knowledge as such, and nothing to the otherwise good scientific reputation of Dr. Horney. It certainly will not be appreciated by trained psychoanalysts. The general practitioner, who knows little about it, will fail to understand its meaning and implications. Unfortunately, it is likely to get into the hands of the lay public, to whom the author and the publisher make a most obvious appeal, but where it is likely to do much more harm than good. The general public should have no greater interest in psychoanalysis as a therapeutic and medical procedure than it has in abdominal surgery or ophthalmology. The reviewer fears that Dr. Horney suffers from a "popularity complex" and is overreaching herself in order to reach the public. Let us hope that the book will be the last of its type and will not be followed by such popular expositions as "How to Interpret Your Own Dreams" or "Psychoanalysis by Correspondence."

B. K.



THOMAS JEFFERSON MEMORIAL, DEDICATED IN WASHINGTON ON APRIL 13

## THE PROGRESS OF SCIENCE

### DEDICATION OF THE JEFFERSON MEMORIAL<sup>1</sup>

ON April 13, 1943, the two hundredth anniversary of the birth of Thomas Jefferson, the memorial a proud nation has erected in his memory was dedicated. Engraved on its marble walls are a few of his words that express implicitly the Declaration of Independence, the Four Freedoms and the high aspirations of scientists.

*I have sworn upon the altar of God hostility against every form of tyranny over the mind of man.*

Jefferson is known as the author of the Declaration of Independence, successor to Franklin as United States Minister to France and President of the United States for two terms (1801-1809), but of himself he once wrote, "Nature intended me for the tranquil pursuit of sciences by rendering them my supreme delight." Yet it was his fate to be one of the foremost leaders of the American Revolution, to witness the storming of the Bastile in 1789 as another people plunged into revolution, and to spend forty years of his life in political service of his country during the stormy period when it was evolving into an independent nation.

In spite of his arduous political life, Jefferson always maintained his interests in science. While he was minister to France he was respected and admired in literary and scientific circles as well as by statesmen. In fact, he successfully challenged Buffon's opinion that animals had degenerated in the Western Hemisphere. He sought out and sent to America many kinds of plants and animals that he thought might be useful in the New World. In 1796 he was elected President of the American Philosophical Society, and when he went to Philadelphia the following year to take the oath

<sup>1</sup> Text by Dr. F. R. Moulton; photographs by Abbie Rowe, printed through the courtesy of The National Park Service.

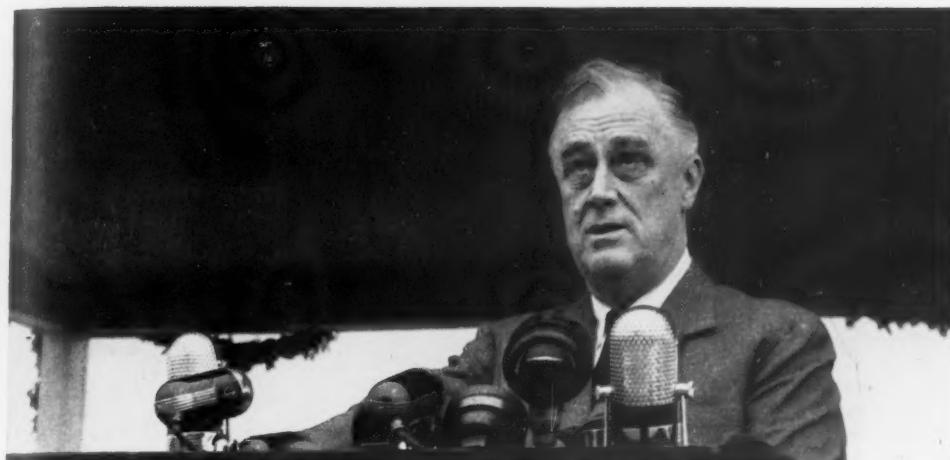
of office as Vice President of the United States, he took with him a collection of fossil bones of a large mammal and the manuscript of a memoir on them for presentation before the American Philosophical Society. He was President of the Society again during his two terms as President of the United States.

Jefferson's taste found their fullest expression in the building of beautiful Monticello on a high rounded hill overlooking Charlottesville, Virginia, with the lovely Blue Ridge a few miles beyond to the west. He was his own architect for the thirty-five-room mansion to which he took his bride on New Year's day, 1772. The timbers in it were cut in his own forests, the rocks were taken from his hills, the bricks were made from his soil, the nails were fashioned in his shops. He laid out the principal rectangle, the octagonal central hall, the living and dining rooms, the guest chambers, the terraces, the kitchens, the servants' quarters, the stables, the spacious lawns and gardens, and he planted the shrubs and trees. His large clock and weather vane were designed to be equally visible from the interior and the outside, and every room carried the marks of his thoughtful attention. This home and the University of Virginia are expressions of a Jefferson, a very human and noble Jefferson, largely only a name to the present generation, but whose lofty mind and high purposes will become somewhat known by the millions who will visit the marble memorial by the Potomac.

No one can evaluate the innumerable influences, hereditary and environmental, that with infinite interactions determine the qualities of an individual. But Jefferson left words expressing the influence of three of his teachers in the College of William and Mary on his life:



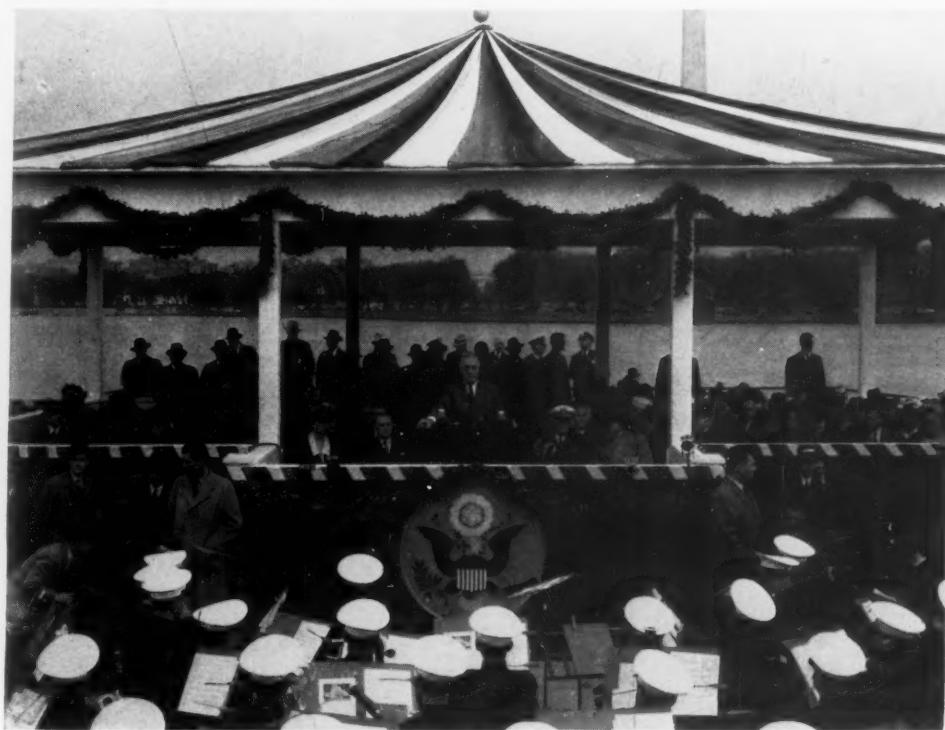
STATUE OF THOMAS JEFFERSON IN THE MEMORIAL BUILDING  
*Left to right:* OTTO R. EGGERS, ARCHITECT; DR. FISK KIMBALL, MEMBER OF THE EXECUTIVE COMMITTEE OF THE THOMAS JEFFERSON MEMORIAL FOUNDATION; STUART G. GIBBONEY, CHAIRMAN OF THE COMMISSION; SENATOR ELBERT D. THOMAS, VICE CHAIRMAN; RUDOLPH EVANS, SCULPTOR.



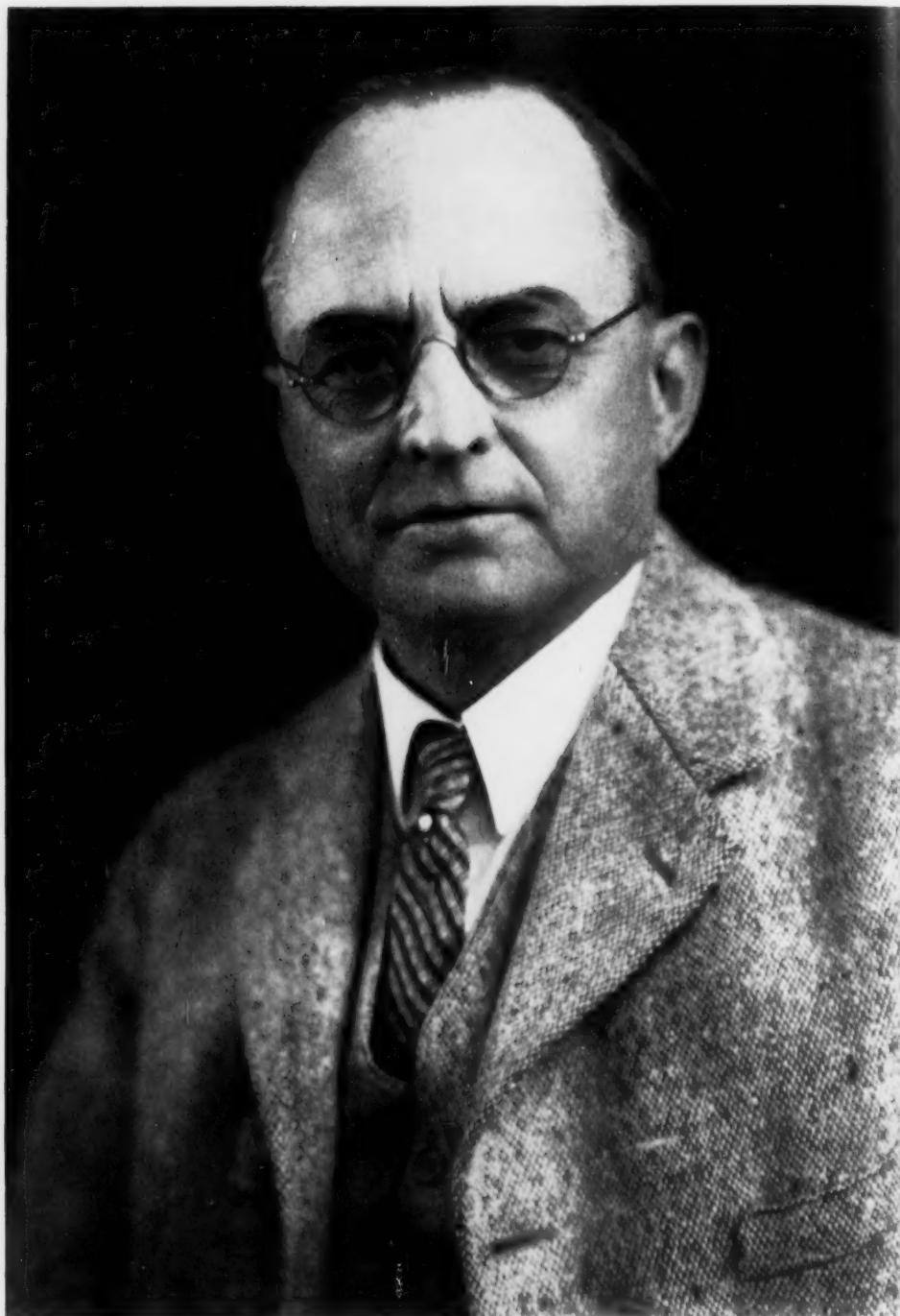
PRESIDENT ROOSEVELT SPEAKING AT THE DEDICATION ON APRIL 13.

"Under temptations and difficulties I would ask myself what would Dr. Small, Mr. Wythe or Payton Randolph do in this situation? What course in it will

insure me their approbation? I am certain that this mode of deciding on my conduct tended more to correctness than any reasoning powers I possessed."



DEDICATION CEREMONIES OF THE JEFFERSON MEMORIAL  
CHAIRMAN GIBBONEY AND MRS. ROOSEVELT ARE SITTING TO THE RIGHT OF THE PRESIDENT. THE  
UNITED STATES MARINE BAND STANDS IN FRONT OF THE GRAND STAND.



DR. WILLIS RODNEY WHITNEY

DR. WILLIS RODNEY WHITNEY, RECIPIENT OF THE JOHN FRITZ MEDAL<sup>1</sup>

It is unfair to any man to try to describe him by a single quality. He may be many things to different people: a loyal friend, an inspiring leader, a good fellow, an enthusiastic investigator, a pioneer, a practical realist.

Dr. Whitney is all of these. But his most conspicuous quality is scientific curiosity. He is a pure scientist, if we define pure science as that which is motivated by curiosity. I think Dr. Whitney would say that pure or impure is all the same to him; but that curiosity is the best basis for research of any kind. He once wrote: "The asset of engineering is exact knowledge. The valuable attributes of research men are conscious ignorance and active curiosity." His most frequent comment about research men is that they are not curious enough. The goal of research, he believes, is to find out how Nature works, rather than try to make it fit into our plans or theories. In his own words, "We advance more often by finding in Nature that which we may learn to use than by making or forcing from Nature that which we think we want."

The world will never know the full extent of Dr. Whitney's scientific contributions, because they are inextricably bound up with the work of those whom he directed. Stimulating suggestion was the feature of his daily rounds of the laboratory, but he claimed no credit for himself. I do not think it was so much conscious generosity, as a fundamental point of view. His philosophy of life calls for devotion to the search for Truth first, with personal considerations secondary and more or less immaterial as far as he himself is concerned. The fact that he nevertheless gained an undying reputation is one of the wonderful paradoxes of human psychology, perhaps one of the laws of Nature as fundamental as the physical laws which he sought to learn.

<sup>1</sup> Awarded jointly by a group of national engineering societies.

The work for which Dr. Whitney is best known is the organization and direction of the Research Laboratory of the General Electric Company. This was a pioneering task. Industrial research laboratories were not new, but their activities had been almost exclusively devoted to product development and improvement. Fundamental research was confined mostly to universities. Could it be done profitably in an industrial laboratory?

Mr. E. W. Rice, at that time chief engineer of the General Electric Company, had the vision that it could. He looked for a young man who might translate this vision into reality. He found Willis Whitney, a young assistant professor at M. I. T., who was having a fine time with his research and not at all concerned about another job, least of all a job of organization.

It was typical of Mr. Rice that he did not choose an organizer. Dr. Whitney is not an executive type. He hates routine. Conferences and committees bore him. Budgeting and bookkeeping are not among his interests. Nor has he that passion for being at the head of something, which characterizes many leaders. Yet he is one of the most successful leaders I have known. Perhaps the conventional method of leadership is not the only one, or even the best one. Inspiration and example may be more important than direction, at least in the realm of research. What Mr. Rice saw in Dr. Whitney was the scientist, whose enthusiasm for research was infectious. His faith in the man he chose never wavered.

The General Electric Laboratory was started as an experiment in industrial research; namely, a research laboratory that would include fundamental investigations as well as product improvement. That the two should go together is essential, since fundamental research leads to products, which must be nursed through

infancy before being passed on to the factory. There appears, however, to be a tendency, similar to the law of entropy, for laboratory activities to drift always downward toward practical applications. Dr. Whitney's success in stemming this tide, and keeping the balance between fundamental and applied science, is one of his great accomplishments. It attests his faith in the value of pure research, as well as faith in him on the part of the officials of the General Electric Company.

In organizing the laboratory, Dr. Whitney proceeded in the same manner as in his other scientific experiments. He began cautiously, on a small scale, feeling his way. During the first year, three days of each week were spent in Schenectady, and the other three in Boston. By the next year, the laboratory was a full-time job for him, with six assistants. Each year witnessed a small, well-consolidated growth, as in *Nature*. In this way, his own personality became indelibly impressed on the organization which grew up under his care. His fairness and strict honesty, thus transmitted, became the basis of the spirit of coopera-

tion that has been the laboratory's greatest asset. His belief in the value of fundamental research, and his enthusiasm for experiment, have become part of that mysterious something which we call the spirit of the laboratory.

I can not remember ever having been reprimanded or criticized by Dr. Whitney. His method was encouragement. He almost never discharged an employee. Those who did not belong in the group came to realize it as a mutual condition, and left for their own interest.

In 1932, at the age of sixty-five, Dr. Whitney turned the direction of the laboratory over to Dr. Coolidge, thus finding opportunity to devote himself to experimental research, his first love. He comes to the laboratory every day. If I start early enough in the morning, I frequently have the pleasure of being picked up by him on his way to work, for he is still the first one in in the morning, as he has always been. To-day he is one of the gang. When he decides to stop coming to the laboratory, I think some part of him will still be there, inspiring and guiding our work.

ALBERT W. HULL

#### JOÃO BARBOSA RODRIGUES AND A NEW BRAZILIAN POSTAGE STAMP

MANY illustrious students of the abstract, the theoretical and the physical sciences have fittingly been honored for their accomplishments and their gifts to the advancement of human life and its comforts. A myriad of channels and devices have been utilized in bestowing these public compliments. Monuments have been erected, parks and even cities have been dedicated in the names of the students of the sciences. During the past decade a very effective medium of public compliment has internationally been employed with increasing frequency. Governments have given their sanction to the issuance of special postage stamps, individually designed for the single purpose

of giving signal honor to great men and their deeds. These special pictorial messages, through the correspondence of the masses of the people, destined to the far corners of the globe, act as silent educators to the recipients wherever they may be.

Brazil has made good use of this broad medium of publicity to inform the world of her illustrious sons. By a 1942 decree, Getulio Vargas, President of the great South American land of coffee and rubber, of iron and cattle, of song and commerce and culture, authorized the preparation of a special postage stamp to do honor to a great scientist, the botanist Barbosa Rodrigues. His sixty-seven



THE BRAZILIAN STAMP HONORING THE BOTANIST, BARBOSA RODRIGUES

years were replete with research, study and accomplishment.

Born in Rio de Janeiro on June 22, 1842, João Barbosa Rodrigues was a naturalist of unquestioned merit. Judging, however, by some of the biographies that have come to light since his death on March 6, 1909, Barbosa Rodrigues in his early youth was more inclined to literature than to the serious studies of the botanical science. During his literary activities he wrote and published a number of books, short stories and novels that brought him fame as a popular writer; he also was the founder of a school journal called "Semana dos Meninos," considered the first of its kind ever to have appeared in Brazil.

He finished his course at the Instituto Comercial in Minas Gerais with highest honors of his class and was awarded a prize in economics. It was not until later, after he had finished his studies, that Barbosa Rodrigues devoted all his attention to the study of botany, archeology and anthropology. Except while he was at school he lived with his father of the same name, in São Gonçalo de Sapu-

cá in the Province of Minas Gerais where they had moved shortly after his birth. His father was a Portuguese subject and his mother, Maria Carlota da Silva Santos, was a Brazilian. She died while her son was a small boy, after the family had moved from Rio de Janeiro to Minas Gerais.

After his return to Rio de Janeiro, following the completion of his schooling, he was appointed Secretary of the Colégio Pedro II where he also taught drawing. While at this post he revealed his inherent tendency for the natural sciences in the study of which he acquired considerable knowledge. The Imperial Government of Brazil sent him to the Provinces of Para and Amazonas to make scientific investigations, especially in connection with the palm trees of those areas. In the course of his work Barbosa Rodrigues discovered and classified a large number of new species which had not been found by other scientists, among them the famous Martius and also Richard Spence and Alfred Wallace.

After having collected considerable data on the palm trees of the Amazonian



VICTORIA REGIA STAMP

SHOWING A FLOWER AND PLATTER-LIKE LEAF OF VICTORIA REGIA, A LILY OF THE AMAZON VALLEY, WHICH WAS STUDIED BY RODRIGUES. IN THIS REGION THE NATIVES GRIND THE SEED POD INTO A STARCHY FLOUR FOR FOOD.

region, Barbosa Rodrigues endeavored to obtain a subsidy from the Government of Brazil for the publication of the result of his investigations. He was, however, unsuccessful in this attempt. Meanwhile, Dr. Reichembak of Vienna, Austria, invited Barbosa Rodrigues to be his collaborator in the preparation of a tract on Brazilian orchids, a task that had been undertaken by the former some years prior but which he had been unable to complete due to his inability to locate the specimens for study in their native habitat. Some time after this, Dr. Eichler invited Barbosa Rodrigues to perform the same work with Dr. Kraenzlin, Reichembak's successor in Vienna. In his letter to Barbosa Rodrigues, dated July 22, 1881, Kraenzlin wrote as follows: "Les espèces nouvelles seront publiées sous le nom et l'autorité de Barbosa Rodrigues and Kraenzlin ainsi que tout

l'œuvre. C'est à vous de dire oui ou non. Vous êtes le premier et vous avez mérité l'honneur."<sup>1</sup>

Two years after he had started his studies on this scientific subject and while still engaged in the work, Barbosa Rodrigues met Dr. James Trail, a British explorer who had come to the Amazon on a scientific mission for his Government. Barbosa Rodrigues informed the British representative of his discoveries in botanical fields and the two scientists "herborized" together. Some of the specimens that had been discovered, classified and drawn by Barbosa Rodrigues were sent to the Kew Gardens in London. Dr. Trail, however, claimed full credit in regard to these discoveries for himself and as a result Barbosa Rodrigues energetically proclaimed priority for his work. The subject was given consideration by the Instituto Historico e Geographico Brasileiro where Barbosa Rodrigues established beyond question that about the time Dr. Trail had arrived in Para, he himself had already studied and drawn the new species and submitted a detailed report to his Government.

In addition to the research in the flora and the fauna of Para and Amazonas, Dr. Barbosa Rodrigues undertook another task of wholly different character, namely, that of educating and Christianizing the Indians of the Cricianas tribe. His work has a strong tendency toward pacifying these warring Indians and raising their standard of civilization. In the conduct of this undertaking he studied the language and customs of the Cricianas and left several decidedly useful books in regard to both.

Dr. Barbosa Rodrigues is credited with being the first layman, unschooled as a physician or a chemist, to have made a

<sup>1</sup> "The new species, as well as the whole work, will be published under the name and authority of Barbosa Rodrigues and Kraenzlin. It's up to you to say 'Yes' or 'No.' You have been the first and deserve the honor."—"Diccionario Bibliographico Brazileiro" by Antonio Vieitorino Alves Sacramento Blake, pp. 359-65.

thorough scientific study of *curare*, the deadly plant poison extensively used by the Indians in poisoning their arrows. He found that sodium chloride, common table salt, was an effective antidote for the lethal action of the violent poison which the Indians had so commonly used in battle. He also made numerous archeological explorations, and one of his most notable discoveries in that field was the *Muirakitan*, an idol of the natives who inhabited the Amazonian region long before Columbus arrived in America.

Dr. Barbosa Rodrigues was a prolific writer of books, reports and monographs on plants and archeology, still recognized by students of those sciences. Outstanding among his works, however, the following should be mentioned: "Enumeraatio Palmarum"; "Sertum Palmarum"; "Genera et Species Orchidearum Novarum"; the last mentioned consists of seventeen volumes. He was a member of several learned and scientific societies and institutions of Europe, among them being the botanical societies of Vienna and Edinburgh, and also of the Instituto Historico e Geographico Brasileiro of Rio de Janeiro.

The 300 and the 1000 reis Brazilian stamps of 1937 dedicated to the Jardim Botanico, located about twenty minutes' drive from the metropolitan center of Rio de Janeiro, are closely associated with the life of Barbosa Rodrigues. Although founded long before he was born, the famous Garden was broadly expanded and developed while he acted as its director, beginning in 1890. Shortly after reaching Brazil in 1807 the Reigning Monarch, Prince Dom João (later King John IV of Portugal, Brazil and Algarves) ordered the preparation of a selected plot of ground for the development of botanical specimens. This was known as the Royal Botanical Garden and has since been renamed the Jardim Botanico and expanded until it now covers an area of some one hundred



JARDIM BOTANICO STAMP

DEPICTING THE AVENUE OF GIANT PALM TREES AND FOUNTAIN IN THE GARDEN. AT THE OTHER END OF THE AVENUE OF TREES IS A SMALL GREEK TEMPLE DEDICATED TO THE GODDESS OF PALMS WHICH WAS ERECTED BY RODRIGUES.

forty acres, being classed as one of the outstanding botanical preserves of the world. Its present beauty is due largely to the rearrangements, the monuments, the ponds and paths planned and perfected by Barbosa Rodrigues. Principal among these monuments is the Dea Palmaris, a small Greek temple dedicated to the Goddess of Palms, located at one end of a long avenue of giant palm trees which reach an average height of one hundred feet with a girth of approximately ten feet at their base. A view of this beautiful avenue of palms, terminating at one end with the Grecian temple erected by Barbosa Rodrigues and, at the other, with a beautiful double basin fountain, is depicted on the unusually attractive multi-colored Brazilian postage stamp of 1937. A delightful description of the Jardim Botanico is contained

in a well illustrated article by Dr. F. Lamson-Scribner in THE SCIENTIFIC MONTHLY of January, 1938.

One of the many botanical specimens which received the careful attention of Barbosa Rodrigues was the Victoria Regia which is depicted on an attractive dull violet 1000 reis postage stamp of Brazil, released during 1940 in compliment to the World's Fair in New York. The stamp shows one of the large circular leaves of the Victoria Regia which at times attain a diameter of from six to seven feet. The edges turn up at right angles to form a border eight or nine inches high, giving a platter-like appearance to the leaf and add appreciably to its strength. In addition to the leaf, largest in the lily family, the stamp shows one of the immense blossoms which generally reach the height of flowering beauty during the months of April and May in their native habitat of the Amazon Valley. The natives in the Amazon regions where the Victoria Regia grows in plentitude, use the pod as food, grinding it to flour which is said to contain a large percentage of starch.

A close analysis of the life of João Barbosa Rodrigues and the lasting accomplishments which glorify his memory, leads to many fields. Prime among them, however, his contributions to the development of the botanical science stand preeminent as those of a pioneer, a discoverer and an authority whose decision has but seldom been questioned.

Another outstanding South American botanist who has enjoyed the signal honor of portraiture on a postage stamp was Francisco Antonio Zea of Colombia. An accomplished naturalist, Zea was called to Bogotá at an early age to take charge of the National Botanical Gardens there, but his work in that direction was abruptly halted as a result of court action due to his having become implicated with Antonio Nariño in the publication of "The Rights of Man." Paradoxically, while in exile under order of the Crown's Judiciary, Zea won an appointment at the Botanical Garden of Madrid where he was designated and became famous throughout Europe as a professor of natural sciences.

A. B. TIGRE AND ALBERT F. KUNZE

#### THE USE OF AMINO-ACIDS TO SUPPLANT OR SUPPLEMENT BLOOD PLASMA

HUMAN blood plasma obtained from donors and injected intravenously has achieved widespread use in patients suffering from various diseases, in surgical shock from severe hemorrhage, and in burns. The relative ineffectiveness of injections of solutions of saline and glucose in such conditions is now generally known. Plasma owes its peculiar effectiveness, in large measure at least, to the fact that it contains in solution six or seven grams per cent. of protein which because of its large molecular size exerts a colloidal osmotic pressure. This property of plasma, as postulated by Starling nearly fifty years ago, is essential in order to maintain the circulation of the

blood and a balanced fluid interchange between the blood and the tissues. In the majority of severe cases, at least one liter of plasma is required as an initial injection and such an amount requires the bleeding of four donors and considerable processing. Because of this inevitable practical difficulty and for other reasons, various solutions have been investigated in the hope that they could act as blood substitutes. For example, certain animal and vegetable proteins form colloidal solutions in water and could be used except for the well known fact that foreign proteins, when injected, produce dangerous anaphylactic reactions. Curiously enough, gelatin does

not have this effect and though tried in the past, it has not achieved general use because of many difficulties. Other substances, non-protein in nature (*e.g.*, acacia, pectin) also form colloidal solutions in water and thus simulate the behavior of plasma proteins. Although good results have followed their use, they, too, are foreign substances, and the body tries to get rid of them in one way or another.

An entirely different principle is involved in the injection of the simpler units of protein obtained by thoroughly hydrolyzing or digesting animal or vegetable proteins. The idea here is not to inject a solution which simulates the colloidal effect of plasma proteins, but to inject the common building stones of all proteins, *i.e.*, amino-acids and polypeptides, thus enabling the body to manufacture its own new plasma proteins or, indeed, proteins in any other part of the body. Nearly all protein can be hydrolyzed and will yield a mixture of amino-acids and polypeptides; if a proper protein is selected and appropriately hydrolyzed, the resulting mixture will contain all the essential amino-acids present in plasma proteins.

This approach to the therapy of diseases requiring plasma transfusions is essentially a biochemical or metabolic one. From such a point of view a fundamental fact is the inability of the body to replace rapidly the plasma protein loss in, say, a severe hemorrhage. The loss of the red cells has long been known to be of secondary importance to the loss of plasma itself. While the loss in blood volume is adequately restored from large extracellular stores of fluid, unfortunately this fluid carries little protein, and this little apparently is mobilized from the liver cells. Thus the loss of blood leads to a lowering of the colloidal osmotic pressure of the blood, and a week or more is required before it is corrected spontaneously. Consider how strange

this is: following the loss of 2000 cubic centimeters of blood, a shift of an equal volume of protein-free fluid may restore blood volume, but this fluid lacks about sixty grams of plasma protein which is urgently needed and whose absence may prove fatal (or its injection may promptly save life). Yet at the same time kilograms of tissue protein are distributed everywhere without being used. The liver is probably a key organ in this situation because it is the manufacturing source of all endogenous plasma protein. After a severe hemorrhage the liver gives up what protein it can spare and become depleted, and must then make more protein from amino-acids or polypeptides, which in turn originate from the breakdown of other tissue proteins, unless, of course, it is supplied from without. It is this exogenous supply which offers a therapeutic approach.

Although the injection of hydrolyzed protein is a new method of therapy, it has already been used extensively as a means of intravenous protein alimentation in malnourished patients unable to take any food by mouth. Indeed, in such nutritionally depleted individuals, plasma transfusions were, until the introduction of hydrolyzed protein, the sole method of administering protein parenterally. In addition to its greater cost and inconvenience, plasma in such cases is actually inferior to hydrolyzed protein for other reasons, *i.e.*, amino-acids being basic building blocks, are able to supply means for correcting not only the deficiency in the blood stream, but deficiencies elsewhere in the body. Plasma, on the other hand, ordinarily corrects only protein loss from the blood; to be utilized outside the blood stream, it presumably must be hydrolyzed to smaller units and perhaps even amino-acids, before other tissues can utilize them for synthesis of their own characteristic protein.

Quite recently experimental studies seem to show that hydrolyzed protein may prove of value in more acute conditions, particularly when there is a sudden loss of plasma protein as from actual hemorrhage or injury. Such a use implies, of course, that the synthesis of new plasma protein can occur rapidly. Considerable evidence has accumulated especially through the work of Schoenheimer with isotopic nitrogen that the metabolism of protein is rapid. Those and other observations furnish a justifiable basis for the use of the building stones of protein in any condition where plasma protein is needed urgently. In the experiments just mentioned surgical shock was produced in dogs by repeated hemorrhage until a fatality ensued. The injection of solutions of hydrolyzed protein to replace the removed blood prolonged life significantly as compared with controls, even those in which citrated dog plasma was injected. The mechanism by which this result was achieved is not entirely clear, but was apparently made possible by enabling the liver to manufacture new plasma protein which permitted the subject to withstand further loss of blood. Thus, histological study of liver sections seemed to indicate that this was true.

Emphasis must be placed on the fact that the hydrolyzed proteins used thus far have no colloidal osmotic pressure and that they can not therefore be considered as a substitute for blood plasma in the true sense of the word. However,

they offer considerable prospect of being valuable as a source of material from which the body may manufacture plasma proteins rapidly and thus spare the need for plasma. These observations, moreover, open an entirely new field of investigation which might be described briefly as the study of protein and amino-acid metabolism in conditions of stress and strain. For example, means may be found to accelerate the normal slow regeneration of protein which follows a severe hemorrhage. Viewed from another angle, nothing is known of the metabolic behavior of proteins which have been only partly hydrolyzed. The utilization of protein hydrolysates may be possible when relatively large aggregates of amino-acids are injected, aggregates which may even be large enough to exert some colloidal osmotic pressure of their own. Only further study will tell. Regardless of these considerations, there remains the practical superiority of solutions of hydrolyzed proteins which are available in unlimited amounts, and are almost as inexpensive to make and give as saline and glucose solutions, in contrast to the inevitable expense, difficulties and limiting factors in preparing plasma. Even if they can only supplement the need for plasma which is so effective in the acute stage of shock, the amino-acids of hydrolyzed protein offer considerable prospect of conserving much of the valuable plasma for more urgent purposes.

ROBERT ELMAN